AN ANALYSIS OF RECENT EXPLANATIONS OF WHY TRANSACTIONS MONEY DEMAND MODELS OVERPREDICT IN THE 1974-1978 PERIOD

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PREFACE

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INTRODUCTION

Purpose of Study

The purpose of this study is to evaluate recent explanations of why transactions models of money demand begin to overpredict in 1974. Transactions models that use sample periods ending prior to 1974 show evidence of forecasting adequacy[1] along with long-term structural stability (Goldfeld, 1973). When these same models are used to forecast in the post-1973 period, they consistently overpredict the demand for money (Enzler, Johnson, and Paulus, 1976; Goldfeld, 1976). In addition, the coefficient estimates of standard money demand equations reflect the apparent breakdown in the money demand relationship when post-1973 observations are included in the sample period.

The stability of the money demand equation is an important issue to the makers of monetary policy. The goals of monetary policy are to contribute toward achieving full employment, price stability, and economic growth. In the short-run, the Federal Reserve attempts to manipulate the growth of nominal income in order to meet these ultimate policy goals. In recent years, the Federal Reserve has announced

[1]Forecasting adequacy is usually judged in terms of root-mean-squared-error, mean error, and mean absolute error. Other methods may be found in Granger and Newbold (1973).

money supply growth targets that are believed to be consistent with the desired growth in nominal income.

The monetary authorities can better achieve the desired growth rate of money income if the demand for money, or alternatively, the growth rate of velocity is predictable. For example, if a nominal income growth rate of 12 percent is expected to be consistent with the Federal Reserve's ultimate policy objectives, and if velocity is expected to grow by 5 percent, then a money supply growth target of 7 percent would be considered consistent with the Federal Reserve's policy goals. If velocity actually grows by 8 percent, then attaining a money growth target of 7 percent would be unnecessarily expansionary. This could result in an inflation rate that is unacceptably high. On the other hand, if the demand for money is underpredicted, or velocity is overpredicted, then the monetary growth target is unnecessarily restrictive. Suspected shifts in the money demand relationship should therefore be studied carefully.

Aside from the importance of the stability issue to monetary policy, there are additional reasons for conducting this study. Even though the literature contains a variety of models explaining the money demand problem, economists do not agree that one particular model (or group of models) represents the definitive explanation of the problem. Additional analysis of the proposed explanations is necessary. Direct comparison of these models is not possible because of differences in data and sample periods. This study makes the proposed models more comparable by re-estimating them with a common data base and a common sample period. By re-estimating the models with the most recently revised data and with sample periods extending beyond 1974, it is possible to observe the robustness of each model with respect to data revisions and changing sample periods.

An additional reason for performing this study is to consider the effects of inflationary expectations on money demand in the post-1973 period. Goldfeld (1976) investigates this issue, but his study is limited. Since the money demand problem arises during a period in which inflation is relatively high, it only seems natural to study the impact of inflation on money demand during this period in more detail.

A Standard Money Demand Equation

Working within the framework of Baumol (1952) and Tobin (1966), Goldfeld (1973) develops a popular model of the transactions demand for money. Several of the studies that attempt to resolve the money demand problem use Goldfeld's model. The Goldfeld equation is:

$$\ln m_t = \beta_0 + \beta_1 \ln y_t + \beta_2 \ln RCP_t + \beta_3 \ln RTD_t + \beta_4 \ln m_{t-1} \tag{1-1}$$

where m_t = the demand for real balances (M_t/P_t),

M_t = the demand for nominal balances,

P_t = the GNP deflator,

y_t = real GNP,

RCP_t = the commercial paper rate, and

RTD_t = the commercial bank time deposit rate.

The lagged dependent variable is included under the assumption that actual holdings of real balances in the current period adjust with a lag to desired holdings. Equation (1-1) employs the so-called real adjustment mechanism which assumes nominal money demand adjusts instantaneously to a change in the price level. In this case the lagged dependent variable is M_{t-1}/P_{t-1}.[2] For the 1952-1972 period, and for subperiods of those years, equation (1-1) yields coefficient estimates that are statistically significant and of the theoretically correct signs. The equation also tracks money demand relatively well in a series of static and dynamic simulations.[3]

In his 1976 investigation of the money demand problem, Goldfeld uses a slightly different version of equation (1-1). Goldfeld tests the hypothesis that the elasticity of money demand with respect to

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[2] The partial adjustment mechanism is written as $(\ln m_t - \ln m_{t-1}) = \lambda(\ln m_t^* - \ln m_{t-1})$ where m_t^* is desired real money holdings, and λ is the speed at which actual money holdings adjust to the gap between last period's stock and the current period's desired stock. The desired real money stock is defined as $\ln m_t^* = \beta_0^* + \beta_1^* \ln y_t + \beta_2^* \ln RCP_t + \beta_3^* \ln RTD_t$. Substituting into the partial adjustment mechanism,

$$(\ln m_t - \ln m_{t-1}) = \lambda(\beta_0^* + \beta_1^* \ln y_t + \beta_2^* \ln RCP_t + \beta_3^* \ln RTD_t - \ln m_{t-1})$$

and

$$\begin{aligned}\ln m_t &= \lambda\beta_0^* + \lambda\beta_1^* \ln y_t + \lambda\beta_2^* \ln RCP_t + \lambda\beta_3^* \ln RTD_t - \\ &\quad \lambda \ln m_{t-1} + \ln m_{t-1} \\ &= \beta_0 + \beta_1 \ln y_t + \beta_2 \ln RCP_t + \beta_3 \ln RTD_t + (1 - \lambda) \ln m_{t-1}.\end{aligned}$$

The last equation is the same as equation (1-1).

The β_j ($j = 1, 2, 3$) represent short-run elasticities, and long-run elasticities are $\beta_j^* = \beta_j/\lambda$. λ is restricted to be between zero and unity. A λ of zero implies that the difference between desired and actual money holdings is never eliminated and that long-run elasticities are not defined. A λ of unity implies immediate adjustment of actual real money holdings to the desired level and that short-run elasticities equal long-run elasticities.

[3] In a dynamic simulation, forecasts of $\ln m_t$ are obtained by replacing $\ln m_{t-1}$ with its previously forecasted value. In a static simulation the actual value of $\ln m_{t-1}$ is used. In this sense, the static simulation places the equation back on track each time a forecast is made.

population is unity and accepts the null hypothesis. He therefore estimates a model where the dependent variable is real, per-capita money balances and where the constraint variable is real, per-capita GNP. Also, Goldfeld employs the so-called nominal adjustment mechanism rather than the real adjustment mechanism. In doing this, he assumes that nominal money demand adjusts with a lag to a change in prices rather than adjusting instantaneously. The only effect on equation (1-1) is that the lagged dependent variable is deflated by P_t instead of P_{t-1}.[4] Goldfeld finds this version to be preferable to the real adjustment version in terms of post-sample predictions. Hafer and Hein (1980) arrive at a similar conclusion for both in-sample and post-sample predictions. As a result of this evidence, the money demand models that are estimated in this study are per capita models employing the nominal adjustment mechanism.

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[4]Expressing the partial adjustment model in nominal terms, one has $(\ln M_t - \ln M_{t-1}) = \lambda(\ln M_t^* - \ln M_{t-1})$ and,

$$\begin{aligned}
\ln M_t &= \lambda(\beta_0^* + \beta_1^* \ln y_t + \beta_2^* \ln RCP_t + \beta_3^* \ln RTD_t + \ln P_t - \ln M_{t-1}) + \\
&\quad \ln M_{t-1} \\
&= \lambda\beta_0^* + \lambda\beta_1^* \ln y_t + \lambda\beta_2^* \ln RCP_t + \lambda\beta_3^* \ln RTD_t + \lambda \ln P_t - \\
&\quad \lambda \ln M_{t-1} + \ln M_{t-1} \\
&= \beta_0 + \beta_1 \ln y_t + \beta_2 \ln RCP_t + \beta_3 \ln RTD_t + \lambda \ln P_t - \lambda \ln M_{t-1} + \\
&\quad \ln M_{t-1}.
\end{aligned}$$

Subtracting $\ln P_t$ from both sides,

$$\begin{aligned}
\ln M_t - \ln P_t = {} & \beta_0 + \beta_1 \ln y_t + \beta_2 \ln RCP_t + \beta_3 \ln RTD_t + \\
& (1 - \lambda)\ln M_{t-1} - (1 - \lambda)\ln P_t, \quad \text{or,}
\end{aligned}$$

$$\ln m_t = \beta_0 + \beta_1 \ln y_t + \beta_2 \ln RCP_t + \beta_3 \ln RTD_t + \beta_4 \ln m_{t-1}.$$

The last equation is equivalent to (1-1) expect that $\ln m_{t-1} = \ln(M_{t-1}/P_t)$.

The Money Demand Problem

The problems associated with the money demand equation in the post-1973 years are illustrated in Tables I and II. In Table I, the results of re-estimating Goldfeld's equation for various years are presented. The estimated coefficients begin to deteriorate after 1974. Specifically, beginning in 1975 the coefficient on RTD_t is not significant, and the coefficient on the lagged variable is not significantly different from unity. The fact that the coefficient on the lagged variable is not statistically different from unity implies a difference in actual money balances and desired money balances is never eliminated and long-run elasticities are undefined.

In Table II, post-sample simulation results from the equation that is estimated through 1973 are shown. The problems associated with the post-1973 period are clear whether the static or dynamic simulation results are considered. In the static simulation, the equation consistently overpredicts, although the errors tend to remain relatively constant between 1975:1 and 1978:3. The equation also consistently overpredicts in the dynamic simulation, with errors that grow larger over time.

Tables III and IV show that the source of the overpredictions of money demand is in the demand deposit component of M-1 and not in the currency component. The demand deposit equation deteriorates in a manner similar to the M-1 equation as the sample period is extended. The currency equation, on the other hand, continues to perform relatively well in the post-1973 years. Post-sample simulations (not shown) tell the same story--the demand deposit equation consistently

TABLE I

ESTIMATES OF THE GOLDFELD MONEY DEMAND EQUATION FOR SELECTED YEARS

Endpoint	Constant	m_{t-1}	y_t	RTD_t	RCP_t	$\bar{R}^2$	SEE	D.W.	rho
1973:4	-.0948	.8165	.1270	-.0356	-.0162	.9964	.0036	1.78	.52
	(6.60)	(14.83)	(6.83)	(3.07)	(5.90)				(6.00)
1974:4	-.0941	.8654	.1146	-.0256	-.0170	.9963	.0036	1.81	.50
	(6.79)	(18.08)	(6.81)	(2.53)	(6.50)				(5.46)
1975:4	-.0856	.9856	.0765	-.0020	-.0148	.9959	.0040	1.79	.45
	(6.11)	(26.15)	(5.42)	(0.24)	(5.39)				(4.87)
1976:4	-.0803	1.0222	.0653	.0057	-.0138	.9962	.0041	1.88	.44
	(5.90)	(32.95)	(5.43)	(0.81)	(5.14)				(4.85)
1977:4	-.0789	1.0300	.0587	.0078	-.0135	.9966	.0040	1.89	.42
	(6.13)	(38.28)	(6.06)	(1.30)	(5.23)				(4.74)
1978:4	-.0793	1.0400	.0576	.0094	-0.140	.9967	.0040	1.87	.41
	(6.36)	(43.45)	(6.56)	(1.81)	(5.63)				(4.62)

Note: The sample period for all equations begins with 1952:2. Each time the equation is estimated the endpoint is moved forward by four quarters. Values in parentheses are absolute t-values.

TABLE II

PREDICTION ERRORS FROM GOLDFELD'S MONEY DEMAND EQUATION, 1974:1-1978:4 (BILLIONS OF DOLLARS)

Date and Summary Statistics			
Year	Quarter	Static Error	Dynamic Error
1974	1	.87	.87
	2	-1.14	.04
	3	-.84	-1.16
	4	-1.83	-3.42
1975	1	-4.25	-8.40
	2	-1.62	-11.60
	3	-1.78	-13.90
	4	-5.64	-19.50
1976	1	-4.26	-24.90
	2	-2.70	-28.10
	3	-5.42	-32.90
	4	-3.12	-35.70
1977	1	-4.74	-39.20
	2	-4.46	-42.40
	3	-3.39	-44.10
	4	-4.35	-45.90
1978	1	-4.50	-47.80
	2	-3.50	-48.70
	3	-4.76	-50.30
	4	-7.38	-54.60
RMSE		3.93	33.25
Mean Error		-3.44	-27.58
Mean Absolute Error		3.53	27.67

Note: These prediction errors are based on forecasts of M_t generated by the first equation in Table I. The predicted value of M_t is obtained by first expressing the equation in nominal terms and then taking the antilogarithm of the predicted value of $\ln M_t$. The lagged prediction error is used in forecasting $\ln M_t$.

TABLE III

ESTIMATED DEMAND DEPOSIT EQUATIONS FOR SELECTED YEARS

Endpoint	Constant	Lagged Variable	y_t	RTD_t	RCP_t	$\bar{R}^2$	SEE	D.W.	rho
1973:4	-.1170 (6.83)	.7866 (12.62)	.1150 (7.04)	-.0377 (3.13)	-.0183 (5.76)	.9951	.0043	1.78	.47 (4.97)
1974:4	-.1045 (6.39)	.8891 (17.68)	.0989 (6.52)	-.0186 (1.89)	-.0199 (6.43)	.9951	.0044	1.82	.46 (4.86)
1975:4	-.0855 (5.49)	1.0187 (29.82)	.0738 (5.59)	.0043 (0.59)	-.0178 (5.55)	.9951	.0049	1.81	.40 (4.24)
1976:4	-.0796 (5.36)	1.0442 (38.75)	.0669 (5.42)	.0092 (1.51)	-.0171 (5.44)	.9948	.0049	1.89	.40 (4.33)
1977:4	-.0792 (5.63)	1.0457 (44.36)	.0664 (5.81)	.0050 (1.77)	-.0170 (5.58)	.9954	.0049	1.90	.40 (4.36)
1978:4	-.0802 (5.78)	1.0463 (49.10)	.0675 (6.01)	.0098 (2.05)	-.0176 (5.88)	.9957	.0049	1.87	.38 (4.28)

Note: The sample period for all equations begins with 1952:2. Each time the equation is estimated the endpoint is moved forward by four quarters. Values in parentheses are absolute t-values.

TABLE IV

ESTIMATED CURRENCY EQUATIONS FOR SELECTED YEARS

Endpoint	Constant	Lagged Variable	y_t	RTD_t	RCP_t	$\bar{R}^2$	SEE	D.W.	rho
1973:4	-.3412 (5.39)	.8747 (27.44)	.1400 (6.24)	-.0279 (3.32)	-.0061 (2.43)	.9983	.0029	2.25	.78 (11.54)
1974:4	-.3522 (5.11)	.8729 (24.73)	.1454 (5.98)	-.0257 (2.84)	-.0073 (2.79)	.9979	.0031	2.17	.80 (12.83)
1975:4	-.3348 (5.16)	.8802 (27.45)	.1412 (6.08)	-.0270 (3.14)	-.0063 (2.50)	.9979	.0031	2.23	.76 (11.25)
1976:4	-.3374 (5.13)	.8809 (28.19)	.1394 (6.03)	-.0271 (3.15)	-.0059 (2.41)	.9978	.0031	2.25	.74 (10.94)
1977:4	-.3247 (5.11)	.8833 (28.89)	.1355 (6.07)	-.0264 (3.12)	-.0055 (2.30)	.9979	.0031	2.24	.74 (11.11)
1978:4	-.3039 (4.84)	.8909 (29.52)	.1268 (5.79)	-.0241 (2.88)	-.0052 (2.19)	.9979	.0031	2.22	.73 (10.90)

Note: The sample period for all equations begins with 1952:2. Each time the equation is estimated the endpoint is moved forward by four quarters. Values in parentheses are absolute t-values.

overpredicts in static and in dynamic simulations while the currency equation tracks that component relatively well.

Explanations of the Money Demand Problem

There is a wide variety of explanations of the money demand problem in the recent literature.[5] Although the specifics differ, some of the explanations are quite similar in terms of identifying the source of the problem. Consequently, the large number of explanations may be conveniently grouped.

The Definitional Explanation

Garcia and Pak (1979a; 1979b), Tinsley and Garrett (1979), and Wenninger and Sivesind (1980) argue that, beginning in the mid-1970s, the M-1 definition of transactions balances is incorrect and that the money demand equation should be respecified in terms of the dependent variable.

This argument stems from the introduction in the mid-1970s of several new financial instruments capable of serving as transactions balances.[6] Since these new instruments are excluded from the M-1 definition, it is reasonable to expect the standard money demand equation will overpredict measured money demand. The argument is also supported by the fact that the dynamic prediction errors from money demand models parallel the growth of the new financial instruments.

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[5]See Berkman (1980) for a discussion of some of these explanations.

[6]These instruments include, among others, NOW accounts, repurchase agreements and money market funds.

In testing the definitional explanation, Garcia and Pak, Tinsley and Garrett, and Wenninger and Sivesind broaden the definition of money by adding selected monetary assets to M-1. This expanded aggregate is regressed on the same set of variables that earlier explains money demand relatively well. The results from the various studies are similar. Reasonable coefficient estimates are obtained for models with sample periods extending beyond 1973, and for models that are estimated through 1973, post-sample simulations track money demand relatively well.

The Omitted Variable Explanation

Hamburger (1977), Friedman (1979), Quick and Paulus (n.d.), Porter and Mauskopf (n.d.), and Kimball (1980) argue that the problem can be explained by respecifying the equation in terms of one or more explanatory variables. With the exception of Porter and Mauskopf, these individuals find empirical support for their proposed solutions. Porter and Mauskopf are unable to test their agrument, but they provide theoretical support for their argument.

Hamburger (1977) believes the equation is misspecified in the interest rates and should be respecified to include a long-term rate and the yield on real capital (the dividend-price ratio). Hamburger's model tends to overpredict in a post-sample simulation, but the errors are relatively small and do not accumulate over time. Hamburger attributes a large part of his model's success to the inclusion of the dividend-price ratio among the explanatory variables.

Friedman (1979) agrees that the dividend-price ratio is the important variable in Hamburger's money demand equation. Friedman also believes, however, that the dividend-price ratio acts as a proxy for wealth and should actually be replaced by a real wealth variable. When this version of Hamburger's model is estimated and is used to forecast money demand, Friedman reports the model performs relatively well, with only a slight tendency to underpredict in the post-sample period.

Quick and Paulus (n.d.), Porter and Mauskopf (n.d.), and Kimball (1980) attribute the breakdown in the money demand relationship to the development of and the intensive use of cash management techniques. They argue that the utilization of these techniques allows for a reduction in average money holdings. The missing variable, therefore, is one reflecting the influence of these cash management innovations on money demand. The implications for the basic money demand equation are different in each of the arguments given by Quick and Paulus (n.d.), Porter and Mauskopf (n.d.), and Kimball (1980). The source of the problem in each of the arguments is the same--record high interest rates that give money holders the incentive to seek out and to use money management techniques.

Quick and Paulus (n.d.) attempt to model cash management methods through a ratchet effect on interest rates. This approach is not unlike that used by Duesenberry (1949) in his study of the consumption function. Quick and Paulus (n.d.) believe that once interest rates penetrate a threshold level, money holders adopt cash management services that allow for economizing on money balances. As interest rates subsequently fall, agents are reluctant to scrap their newly acquired cash management methods immediately. This behavior results in a money demand relationship that changes each time interest rates penetrate a newly established threshold level. Quick and Paulus attempt to model this changing relationship by including in their equation a proxy for cash management techniques--a past-peak interest rate variable. In a very brief post-sample simulation, the Quick and Paulus equation does not tend to overpredict money demand.

Porter and Mauskopf (n.d.) use the Miller-Orr (1966) model of money demand in concluding that the adoption of cash management methods reduces the firm's demand for demand deposits. In the Miller-Orr model the scale variable is the firm's short-term cash flow variance rather than real GNP. According to Porter and Mauskopf (n.d.) the adoption of cash management techniques reduces the firm's short-term cash flow variance and in turn reduces the firm's demand for demand deposits. Porter and Mauskopf argue that any transactions demand model using real GNP as the scale variable will overpredict beginning in the mid-1970s since business firm cash flow variance is reduced at this point.

Kimball (1980) points out that the nature of cash management methods requires the use of wire transfers to consolidate and to disburse receipts. In his equation, Kimball includes a variable measuring the number of wire transfers to serve as a proxy for these new methods. As the other researchers, Kimball finds his model forecasts relatively well in a post-sample simulation.

Another variable that may explain the overpredictions of money demand is an expected inflation variable. The literature devotes little attention to the impact of expected inflation on the demand for money in the mid-1970s. Goldfeld (1976) investigates this issue and reports that expected inflation, while significant in the money demand function, does not explain the overpredictions occurring after 1973. Goldfeld's investigation is limited in several ways. For example, Goldfeld considers only one model of inflation (a distributed lag on past inflation rates). Also, inflation is assumed to influence the demand for money over the entire 1952-1973 sample period. If Johnson (1972) is correct in stating that expected inflation does not enter the money demand function as long as the public perceives inflation to be "mild", then it is inappropriate that Goldfeld (1976) includes an inflation variable in his equation for the entire 1952-1973 period. The inflation rates for the 1950s and early 1960s are low relative to the inflation rates of the latter 1960s and early 1970s.[7] Inflation also displays a definite upward trend beginning around 1966 that continues through 1974. By using one inflation model covering the entire 1952-1973 period, Goldfeld assumes that at time t+j a money holder not only uses the inflation of time t+j-1, t+j-2, ..., t+j-q in forming a forecast of inflation but also uses the information of time t+j, t+j+1, ..., t+j+r. Of course this latter information set is not available at time t+j. This procedure implicitly assumes that the inflation model is stable over the entire 1952-1973 period. These years include a period of mild inflation, a period of accelerating inflation, a price freeze, a gradual price decontrol, and another period of increasing inflation. It is unlikely that one model of inflation can adequately represent the entire period, and this implies that Goldfeld's results may not be acceptable.

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[7]Between 1952 and 1965, inflation averages 2.0 percent. Between 1966 and 1974, inflation averages 4.95 percent.

The Incorrect Estimation

Technique Argument

Hafer and Hein (1980) produce results that indicate the money demand function is stable when it is estimated in first-difference form. Thus, according to Hafer and Hein, the problem is econometric in nature, and the solution becomes one of choosing the correct estimation technique.

Estimating models in first-difference form is often suggested as a method for dealing with certain econometric problems. Granger and Newbold (1974) recommend this technique in order to avoid estimating models possessing nonstationary error series. Although the form of the error series is never known, Plosser and Schwert (1978) show that the penalty associated with overdifferencing is not as great as that associated with underdifferencing. Granger and Newbold (1974) also advocate differencing as a method for eliminating the trend and (a portion of) the autocorrelation in the dependent and in the explanatory variables. The logic of this suggestion is that the true relationship between variables is to be found in the residuals of the respective series after all time dependency is removed. Differencing is a first step in discovering this true relationship, but modeling the equation as a transfer function would be more appropriate.[8]

Outline

The remainder of this study is organized around an evaluation of the proposed solutions to the money demand problem that are discussed

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[8] See Box and Jenkins (1976).

above. The analysis is limited to these proposals; no new models of money demand are introduced.

Each group of explanations is discussed in a separate chapter. The definitional explanation is discussed in Chapter II. Chapter III analyzes the omitted variable explanations. Included in this chapter is a more comprehensive examination of the effects of expected inflation on the demand for money. Chapter IV evaluates the incorrect estimation technique argument of Hafer and Hein. These three chapters are organized in the same way. A review of a particular argument precedes a presentation of the original evidence supporting that argument. Additional evidence is then given that is either supportive of or in conflict with that position. In this manner some of the explanations are eliminated as solutions to the money demand problem. Chapter V contains a summary of the empirical results.

The additional empirical evidence that is presented in Chapters II, III, and IV is based on quarterly data. Unless otherwise indicated, the data are supplied by the Federal Reserve Bank of Kansas City. The period of concern is 1952-1978. This period is chosen because the primary focus of this study is on the weakening of money demand that occurs in the mid-1970s. Recent evidence indicates a possible reduction in money demand in late 1978. This event coincides with recent regulatory changes in the financial sector[9] and is considered to be a matter for further research. Unless otherwise stated, money is defined according to the M-1 definition.

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[9]NOW accounts were introduced in New York in October 1978 and in New Jersey in December 1979. ATS accounts were introduced nationwide in November 1978.

CHAPTER II

AN ANALYSIS OF THE DEFINITIONAL EXPLANATION OF THE MONEY DEMAND PROBLEM

Introduction

The definitional explanation of the money demand problem attributes the overpredictions of money demand to the use of M-1 as the definition of the money supply. Due to the growth of new money assets (capable of serving as transactions balances) in the financial sector, researchers who espouse the definitional explanation believe M-1 understates total transactions balances. Intuitively, the argument makes sense because of the recent developments in the financial sector and because the growth of the new money assets closely approximates the prediction errors from standard money demand models. The explanation also receives apparent empirical support in a series of recently published articles.

During the 1970s, bank and thrift institutions introduced a number of new checkable deposits that were excluded from the traditional definition of M-1. These included NOW accounts, credit union share drafts, ATS accounts and demand deposits at thrift institutions. Also, money market mutual funds offered shares redeemable by check (MMF shares), while corporations adopted cash management methods that allowed them to convert demand deposits into highly liquid repurchase agreements (RPs).[1]

[1] In a repurchase agreement, a bank borrows the excess demand deposits of a large customer using government securities as collateral.

While the new liquid assets could have conceptually been considered as transactions balances, they were excluded from M-1. If money holders treated these new assets as transactions balances, it seemed reasonable to expect that money demand models which explained total money holdings would have overpredicted.

Perhaps as compelling as the institutional developments in the financial sector is the fact that the growth of the excluded liquid assets parallels the prediction errors from standard money demand models. This is shown in Table V where the prediction errors from the Goldfeld equation are compared to the volume of the new checkable deposits, MMF shares, and RPs. While the new money assets are significantly larger than the prediction errors in 1974, the two series more closely approximate one another between 1975:4 and 1978:4. In this period the average value of the new money assets is only slightly smaller than the average value of the prediction errors.

At the empirical level, Garcia and Pak (1979a; 1979b), Tinsley and Garrett (1978), and Wenninger and Sivesind (1979) report the results of estimating standard money demand models where money is expanded to include all, or a portion of, the new money assets that appear in Table V. Their findings indicate the money demand problem is no longer evident when money is defined to include these new assets.

The term of the agreement varies, but many are executed on the overnight basis; i.e., the transaction is reversed the next day. The bank customer benefits in this case since it earns interest on otherwise non-interest earning demand deposits, while the bank benefits since it replaces a demand deposit liability with a liability to federal funds purchased. The latter liability was not covered by reserve requirements in the mid-1970s, so banks were able to reduce their required reserves with each RP transaction. Further details concerning RP's and federal funds may be found in Smith (1978) and in Lucas, Jones, and Thurston (1977).

TABLE V

DYNAMIC PREDICTION ERRORS FROM THE GOLDFELD MONEY DEMAND EQUATION AND THE NEW MONEY ASSETS (BILLIONS OF DOLLARS)

Year	Quarter	Dynamic Prediction Errors	New Money Assets
1974	1	.87	15.20
	2	.04	17.00
	3	-1.16	18.80
	4	-3.42	18.20
1975	1	-8.40	17.60
	2	-11.60	19.70
	3	-13.90	20.50
	4	-19.50	20.60
1976	1	-24.90	21.50
	2	-28.10	26.00
	3	-32.90	29.10
	4	-35.70	30.90
1977	1	-39.20	32.10
	2	-42.40	35.70
	3	-44.10	38.40
	4	-45.90	41.40
1978	1	-47.80	43.90
	2	-48.70	46.80
	3	-50.30	49.80
	4	-54.60	57.70

Note: The prediction errors are generated by the Goldfeld (1976) equation estimated through 1973 (the first equation in Table I). The new money assets are calculated as the sum of the new checkable deposits, money market mutual fund shares and bank repurchase agreements.

In spite of its appeal, this explanation is weak in several respects. There is some question as to whether MMF shares and RPs should be treated as money (Porter, Simpson, and Mauskopf, 1979). Another problem, and the focus of much of this chapter, is that the regressions using the expanded M-1 do not allow the definitional explanation to be refuted by the data. An alternative test of the definitional explanation, the results of which are presented in this chapter, is able to overcome the ambiguity of the results given in Garcia and Pak (1979a; 1979b), Tinsley and Garrett (1978), and Wenninger and Wivesind (1979). This alternative test is also able to demonstrate that the definitional explanation is invalid. This evidence is presented following a review of the studies providing empirical support for redefining money.

Empirical Evidence in Support of the Definitional Explanation

Each of the three studies that are reviewed in this section uses the same method in testing the definitional explanation--standard money demand models are estimated using a monetary aggregate defined to include the new money assets. Although the monetary aggregates differ in each case, these researchers obtain the same general results. Garcia and Pak (1979a; 1979b) add immediately available funds (IAFs) to M-1. IAFs are measured in various ways, but they essentially consist of federal funds purchased (including RPs).[2] Tinsley and Garrett (1978)

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[2]Garcia and Pak define IAFs to include member bank purchases of RPs as well as member bank borrowings from other commercial banks, savings banks, savings and loan associations, domestic offices of foreign banks and the Export-Import Bank.

add only a portion of IAFs to M-1, while Wenninger and Sivesind (1979) add certain liquid assets to M-1B.

Garcia and Pak

Garcia and Pak (1979a; 1979b) argue that as early as 1968 the measured money stock is understated because of the growth of IAFs. Since some IAF transactions are executed on an overnight basis (overnight RPs), Garcia and Pak believe that this portion of IAFs should be included as part of the measured money supply. They, however, are not able to obtain data on overnight IAFs and simple add total IAFs to demand deposits. This produces an "effective" demand deposit series which is used in Garcia and Pak's money demand equation.

Garcia and Pak's estimation results for two sample periods are:

$$\begin{aligned} \ln d_t = \underset{(2.3)}{.832} + \underset{(6.2)}{.558} \ln d_{t-1} + \underset{(5.5)}{.230} \ln y_t - \underset{(7.1)}{.030} \ln RCP_t - \\ \underset{(4.0)}{.048} \ln RTD_t \end{aligned} \qquad (2\text{-}1)$$

$R^2 = .97$ S.E.E. = .0053 RHO = .278

Sample period = 1952:2-1967:4

$$\begin{aligned} \ln d_t = \underset{(1.0)}{.147} + \underset{(13.9)}{.794} \ln d_{t-1} + \underset{(4.4)}{.145} \ln y_t - \underset{(3.8)}{.021} \ln RCP_t - \\ \underset{(2.4)}{.030} \ln RTD_t \end{aligned} \qquad (2\text{-}2)$$

$R^2 = .99$ S.E.E. = .0090 RHO = .354

Sample period = 1952:2-1977:2

where $d_t = (D_t + IAF_t)/P_t$,

D_t = demand deposits,

IAF_t = immediately available funds,

P_t = the GNP deflator,

y_t = real GNP,

RCP_t = the commercial paper rate, and

RTD_t = the passbook savings rate.

Of significance to Garcia and Pak is equation (2-2). Unlike the Goldfeld (1976) equation, (2-2) does not deteriorate in terms of the coefficient estimates as post-1973 observations are added. Also, when equation (2-1) is used in static and dynamic simulations for the 1974:1-1977:2 period, it produces relatively low percentage RMSEs of 1.5 percent and 2.8 percent respectively. Garcia and Pak find the Goldfeld equation (using demand deposits without IAFs as the dependent variable) produces a dynamic RMSE of 12.6 percent over the same period.

Even though there are measurement problems associated with their approach, Garcia and Pak believe their explanation solves the money demand problem. They recognize it is inappropriate to use total IAFs in their model because this figure includes, RPs with maturities that range from overnight to more than 30 days, as well as RPs that are contracted before the end of the banking day. Consequently, a portion of RPs should be considered as coming from other liquid assets rather than displacing transactions balances (Garcia and Pak, 1979b, pp. 708-709). Garcia and Pak recommend that data on total IAFs be published, and until a distinction is made between IAFs demanded on the portfolio account and IAFs drawn from transactions balances, total IAFs should be used in estimating money demand equations.

Tinsley and Garrett

While Garcia and Pak (1979a; 1979b) add total IAFs to demand deposits, Tinsley and Garrett (1978) partition IAFs into those balances demanded on the transactions account and those demanded on the portfolio account. More formally, IAFs are partitioned as:

$$T(IAF) = TY(IAF\colon r,Y) + TP(IAF\colon r,R) \tag{2-3}$$

where $T(IAF)$ = total IAFs,

$TY(IAF\colon r,Y)$ = IAFs demanded on the transactions account,

$TP(IAF\colon r,R)$ = IAFs demanded on the portfolio account,

r = transactions costs,

R = a vector of interest rates, and

Y = income.

Once the partition is achieved, TY is added to demand deposits to form the monetary aggregate that is used in the regression equation. Tinsley and Garrett (1978) report the following results:[3]

$$\begin{aligned}(\ln D/P{\cdot}N + \delta TY/D)_t = &\underset{(2.3)}{-.610} - .022\,\delta_t + \underset{(3.7)}{.0936}\ln y_t + \\ &\underset{(12.6)}{.796}(\ln D/P{\cdot}N + \delta TY/D)_{t-1} - \\ &\underset{(4.2)}{.0166}\ln RTB_t - \underset{(2.4)}{.0311}\ln RCBP_t + \\ &\underset{(0.9)}{.0086}\,\delta_t \ln RFF_t\end{aligned} \tag{2-4}$$

S.E.E. = $.289 \times 10^{-4}$ D.W. = 1.76

Sample period = 1955-1976:4

where $(D/P{\cdot}N)_t$ = per capita demand deposits,

D_t = demand deposits,

P_t = the GNP deflator,

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[3] In constructing the dependent variable in (2-4), Tinsley and Garrett use the approximation, $\ln (D + TY) \simeq \ln D + TY/D$.

N_t = population,

δ_t = a dummy shift variable (δ = 1 for 1970:3-1976:4; elsewhere δ = 0),

y_t = real GNP,

RTB_t = the three month Treasury bill rate,

$RCBP_t$ = the passbook savings rate at commercial banks, and

RFF_t = the federal funds rate.

Tinsley and Garrett's findings show the basic properties of the standard money demand equation are retained when TY is added to demand deposits. A dynamic simulation[4] reveals the Tinsley and Garrett model reduces the dynamic errors from the Goldfeld model by 80-90 percent. These results are found in Table VI.

Tinsley and Garrett conclude that the source of the money demand problem is in the growth of TY that occurs after 1973. They question, however, the practicality of implementing their approach at the policy level since the sampling errors of the coefficients from the partitioning model are ignored in calculating the confidence intervals of the money forecasts. In Tinsley and Garrett's opinion (1978, pp. 84-85), these confidence intervals are "probably severely understated", and they recommend further econometric work be devoted toward obtaining a more exact approximation of TY.

Wenninger and Sivesind

In estimating their model, Wenninger and Sivesind (1979) define

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[4]This is not entirely an out-of-sample simulation since the simulation begins in 1974:1. Due to the lack of observations on TY, Tinsley and Garrett estimate their model through 1976:1.

TABLE VI

DYNAMIC PREDICTION ERRORS FROM THE GOLDFELD AND THE TINSLEY AND GARRETT MODELS, 1974:1-1977:3

Year and Quarter	Goldfeld Model		Tinsley and Garrett Model		
	Error $Bill	Relative Error %	Error $Bill	Relative Error %	% Reduction in Forecast Error
1974:1	-0.6	0	0.6	0	0
:2	-3.9	2	0.1	0	103
:3	-8.1	4	0.6	0	107
:4	-14.0	6	1.0	0	93
1975:1	-21.4	10	-5.3	-2	75
:2	-22.1	10	-3.1	-1	86
:3	-23.7	11	-2.2	-1	91
:4	-28.5	13	-3.4	-2	88
1976:1	-32.2	14	-4.8	-2	85
:2	-32.6	14	-3.8	-2	88
:3	-35.0	15	-4.8	-2	86
:4	-36.6	16	-5.6	-2	85
1977:1	-37.9	16	-6.4	-3	83
:2	-39.3	16	-7.2	-3	82
:3	-39.1	16	-7.1	-3	82

Source: Tinsley and Garrett (1978), p. 81.

money as M-1B plus certain liquid assets. The liquid assets include repurchase agreements at 46 money center banks and money market mutual fund shares.[5] Wenninger and Sivesind note that since these assets can be converted into cash quickly, with little cost, trouble, or risk of capital loss they are more appropriately treated as transactions balances.

Using their definition of money, Wenninger and Sivesind estimate the Goldfeld model and obtain the following results:

$$\ln m_t = \underset{(0.53)}{-.079} + \underset{(18.51)}{.899} \ln m_{t-1} + \underset{(4.37)}{.101} \ln y_t - \underset{(3.84)}{.013} \ln RCP_t - \underset{(2.02)}{.030} \ln RTD_t \qquad (2\text{-}5)$$

$R^2 = .99$ S.E.E. = .0046 RHO = .35

Sample period = 1960:4-1978:2

where $m_t = M_t/P_t$

M_t = M-1B + RP's + MMF's

P_t = the GNP deflator

$m_{t-1} = M_{t-1}/P_{t-1}$

RCP_t = the commercial paper rate

RTD_t = the passbook savings rate at commercial banks, and

y_t = real GNP.

The Wenninger and Sivesind version of the Goldfeld model does not breakdown as post-1973 observations are included. The model also passes a stability test when the assumed break point is 1974:2. Equation (2-5)

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[5]Wenninger and Sivesind (1979) also include savings deposits of corporations and state and local governments to account for a one-time shift out of demand deposits due to the initial offering of these savings deposits.

is also estimated for a sample period that covers 1960:4-1974:2. This model is used in a post-sample dynamic simulation to forecast quarterly growth rates of money, and the results are rather impressive. These results are given in Table VII. While the equation overpredicts in 1975, it appears to be back on track by 1976.

Wenninger and Sivesind believe, as do Garcia and Pak (1979a; 1979b) and Tinsley and Garrett (1978), that they resolve the money demand problem by redefining money. As do the others, they recognize measurement problems add some uncertainty to their results. Nevertheless, they advance their findings as providing general support for the definitional explanation of the money demand problem.

A Critique of the Definitional Explanation

While the definitional explanation and the empirical tests of this explanation are appealing, they may be criticized on two points: (1) the treatment of MMFs and RPs as additions to the quantity of money and (2) the ambiguity of the empirical tests.

Regarding the first point, Porter, Simpson, and Mauskopf (1979) question whether MMF shares and RPs actually replace demand deposits as a form of money in the mid-1970s. They cite evidence to support the view that individuals and businesses use MMF shares and RPs as near money substitutes and as liquid assets. Hence it is unlikely that the funds represented by them would, in their absence, appear on the balance sheet as "demand deposits" rather than as "other liquid assets." By this reasoning, the proper treatment of MMF shares and RPs is as a determinant of the demand for demand deposits and not as an addition to the quantity of money.

TABLE VII

DYNAMIC PREDICTION ERRORS FROM THE WENNINGER AND SIVESIND MODEL, 1974:3-1978:4 (QUARTERLY GROWTH RATES)

Year and Quarter	Prediction Error ($ Bill)
1974:3	-1.4
:4	-1.8
1975:1	-7.1
:2	-3.4
:3	-2.1
:4	-4.0
1976:1	1.3
:2	1.2
:3	-2.2
:4	4.4
1977:1	1.2
:2	0.3
:3	-1.7
:4	-0.5
1978:1	-0.3
:2	2.2
:3	0.5
:4	0.5
Average Error	-0.7
RMSE	2.6

Source: Wenninger and Sivesind (1979), p. 25.

Regarding the empirical tests of the definitional explanation, the regressions using the expanded M-1 do not permit the explanation to be refuted by the data. That is, the regressions using the expanded M-1 guarantee that the prediction errors from dynamic simulations will be small even if the definitional explanation is incorrect. To show this, it is first noted that prior to 1972 the new forms of money are of negligible magnitudes, and thus the traditional M-1 and the expanded M-1 are approximately equal.[6] Consequently, the estimates of the equations using M-1 and the expanded M-1 are virtually the same for sample periods that end prior to 1974.[7] This means that in dynamic simulations each estimated equation produces roughly the same predicted valued of the money supply for the 1974-1978 period.

If there is a reduction in the demand for money in the mid-1970s, then the regressions using expanded M-1 will not be sensitive to this shift. In other words, if the true expalnation of the money demand problem is that the demand for money declines and not that money is understated, then the prediction errors from regression models using published M-1 will be negative and large in magnitude. The errors from the models using expanded M-1 will be small because the volume of new money assets, by coincidence, approximately equals the shortfall in M-1 (Table V). In this case, one will erroneously conclude that an expanded definition of money explains the overpredictions of

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[6]Until 1965, the two are identical. From 1966 to 1971, they do not differ by more than 2 percent. In 1972 and 1973 they differ by only 2 percent and 4 percent, respectively.

[7]This is seen by comparing the results in Goldfeld (1973) with those in Garcia and Pak (1979a; 1979b) or with those in Wenninger and Sivesind (1979).

M-1. It appears that the results given by Garcia and Pak (1979a; 1979b), Tinsley and Garrett (1978), and Wenninger and Sivesind (1979) are ambiguous since these results would be obtained even if money is mismeasured or if the true expalnation of the problem is that the demand for money function experiences a downward shift.

An Alternative Test

The ambiguity results from the use of the money demand function in the test, which makes it impossible to distinguish empirically a shift in demand from an incorrectly defined money supply. An alternative test without this defect uses time series and single equation money supply models to predict money. If the new forms of money replace demand deposits as money in the mid-1970s, then these money supply models will, under certain conditions, overpredict as well. With this in mind, the estimation and forecasting results from time series and single equation money supply models are presented in this section.

The time series methods of Box and Jenkins (1976) are used to estimate money supply and demand deposit models. Each model is estimated as an IMA(2,8) model of the form:[8]

$$(1-B)^2 Z_t = e_t - \theta_4 e_{t-4} - \theta_8 e_{t-8} \qquad (2\text{-}6)$$

where Z_t = the monetary aggregate,

B = a backshift operator such that $BM_t = M_{t-1}$, $B^2M_t = M_{t-2}$, etc., and

e_t = a white noise process ($e_t \sim N(0,\sigma_{ee})$).

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[8] For simplicity the logarithm notation is omitted in equation (2-6). The models, however, are estimated in log form.

The estimation results for the money supply and demand deposit equations are, respectively:

$$(1-B)^2 M_t = \underset{(3.17)}{-.3339}\, e_{t-4} - \underset{(2.51)}{.2840}\, e_{t-8} \tag{2-7}$$

$\chi^2(20) = 14.19$ S.E.E. = .0046

Sample period = 1952:3-1973:4

$$(1-B)^2 D_t = \underset{(3.22)}{-.3443}\, e_{t-4} - \underset{(2.59)}{.2905}\, e_{t-8} \tag{2-8}$$

$\chi^2(20) = 12.98$ S.E.E. = .0055

Sample period = 1952:3-1973:4

where M_t = the M-1 definition of money, and

D_t = demand deposits.

The models appear to be identified correctly in view of the fact that all coefficients are significant and by the relatively low Box-Pierce χ^2 statistics.

If the definitional explanation is correct, then equations (2-7) and (2-8) will overpredict in a post-sample simulation, provided the measurement errors are positive (as the definitional explanation implies) and are increasing at an increasing rate. This is shown by rewriting equation (2-6), using M_t instead of Z_t, as:

$$\begin{aligned} M_t &= 2BM_t - B^2M_t + e_t - \theta_4 e_{t-4} - \theta_8 e_{t-8} \\ &= 2M_{t-1} - M_{t-2} + e_t - \theta_4 e_{t-4} - \theta_8 e_{t-8} \end{aligned} \tag{2-9}$$

If money is understated at time t+j, then:

$$M_{t+j} = M'_{t+j} + a_{t+j} \tag{2-10}$$

where M'_{t+j} = the measured money supply, and

a_{t+j} = the measurement error ($a_{t+j} > 0$).

The one-step-ahead prediction error for time t+j+k+1 ($k \geq 1$) is:

$$\begin{aligned}\hat{v}_{t+j+k}(1) &= M'_{t+j+k+1} - M'_{t+j+k}(1) \\ &= M'_{t+j+k+1} - 2M'_{t+j+k} + M'_{t+j+k-1} + \\ &\quad \hat{\theta}_4\hat{e}_{t+j+k-4} + \hat{\theta}_8\hat{e}_{t+j+k-8} \\ &= (M_{t+j+k+1} - a_{t+j+k+1}) - (2M_{t+j+k} - 2a_{t+j+k}) + \\ &\quad (M_{t+j+k-1} - a_{t+j+k-1}) + \hat{\theta}_4\hat{e}_{t+j+k-4} + \hat{\theta}_8\hat{e}_{t+j+k-8} \\ &= \hat{e}_{t+j+k}(1) - a_{t+j+k+1} + 2a_{t+j+k} - a_{t+j+k-1}\end{aligned} \tag{2-11}$$

Taking expectations:

$$\begin{aligned}E(\hat{v}_{t+j+k}(1)) &= 0 - a_{t+j+k+1} + 2a_{t+j+k} - a_{t+j+k-1} \\ &= -(a_{t+j+k+1} - a_{t+j+k}) + (a_{t+j+k} - a_{t+j+k-1}) \\ &= -\Delta a_{t+j+k+1} + \Delta a_{t+j+k}\end{aligned} \tag{2-12}$$

Sufficient conditions for the expectation in (2-12) to be negative (money is overpredicted) are that the measurement errors are positive and are increasing at an increasing rate.

The one-step ahead errors from the time series equations are presented in Table VIII. The errors are relatively small and are not consistently negative. These results, however, are inconclusive since money could be mismeasured and the equations still predict accurately (i.e., if $-\Delta a_{t+j+k+1} \approx \Delta a_{t+j+k}$). Additional evidence from single equation regression models is required before one may conclude that the definitional explanation is invalid.

In developing the regression models, the money supply framework given in Brunner and Meltzer (1968) is used.[9] In this framework the

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[9]One may also consult Brunner and Meltzer (1964) and Burger (1971).

TABLE VIII

STATIC PREDICTION ERRORS FROM THE TIME SERIES MODELS, 1974-1978

Date and Summary Statistic		Money Supply		Demand Deposits	
Year	Quarter	$Bill	|%|	$Bill	|%|
1974	1	2.8	1.0	2.2	1.0
	2	-2.9	1.1	-2.7	1.3
	3	-0.1	0.1	0.3	0.1
	4	0.0	0.0	-0.7	0.3
1975	1	-0.5	0.2	-0.3	0.1
	2	1.1	0.4	1.2	0.6
	3	1.0	0.3	0.9	0.4
	4	-3.4	1.2	-3.5	1.6
1976	1	1.9	0.6	1.6	0.7
	2	0.8	0.3	0.6	0.3
	3	1.4	0.5	-0.7	0.3
	4	1.3	0.4	1.0	0.4
1977	1	0.5	0.2	0.5	0.2
	2	0.7	0.2	0.5	0.2
	3	0.8	0.2	0.8	0.3
	4	-1.7	0.5	-1.8	0.7
1978	1	0.3	0.1	0.1	0.0
	2	2.7	0.8	2.9	1.1
	3	-1.3	0.4	-1.2	0.5
	4	-3.5	1.0	-4.0	1.5
RMSE		1.8		1.8	
Mean Error		0.1		-0.1	
Mean Absolute Error		1.4		1.4	

Note: The predicted values of the money supply and demand deposits are the antilogarithms of ln M and ln D.

money supply is determined as the product of the monetary base (or unborrowed base) and the money multiplier.

A simplified model of this money supply process is:

$$M = \frac{1+c}{r_D + r_T t + c} (B - f(i_B, i_D)) \qquad (2\text{-}13)$$

where M = the money supply,

c = the currency ratio,

r_D = the required reserve ratio applied to demand deposits,

r_T = the required reserve ratio applied to time deposits,

t = the time deposit ratio,

B = the monetary base,

$f(i_B, i_D)$ = borrowed reserves,

i_B = the rate on 90 day treasury bills,

i_D = the discount rate, and

$B-f(\ )$ = the unborrowed base.

A similar model of demand deposit determination is:

$$D = \frac{1}{r_D + r_T t + c} (B - f(i_B, i_D)) \qquad (2\text{-}14)$$

where d = demand deposits.

Both models recognize that each respective monetary aggregate is the outcome of the behavior of the monetary authority (through B, r_D, and r_T), commercial banks (through their borrowed reserve positions), and the nonbank public (through c and t).

For empirical purposes, the money supply and demand deposit equations are formed as:[10]

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[10] A similar model is presented in Butkiewicz (1978).

$$\ln Z = \beta_1 \ln UB + \beta_2 \ln c + \beta_3 \ln(i_B/i_D) + \beta_4 \ln i_T + e \qquad (2\text{-}15)$$

where Z = the monetary aggregate,

UB = the unborrowed base adjusted for reserve requirement changes,

i_T = the rate paid on time deposits, and

e = a disturbance term.

All other variables are as previously defined. The unborrowed base is included to capture the behavior of the monetary authority; the ratio of the treasury bill rate to the discount rate is included as a determinant of borrowed reserves, the time deposit rate is included to account for movements in the time deposit ratio. No attempt is made to specify the currency ratio, and it is entered directly into the equation. The expected signs of the coefficients are $\beta_1 = 1$, $\beta_3 > 0$ and β_2, $\beta_4 < 0$.

Two methods are used to estimate the money supply and the demand deposit equations. In the first, a method due to Fair (1972) is used to obtain consistent estimates of the regression coefficients. This method also allows one to test the assumption that the error structure follows an AR(p) process. In the second method, the equations are estimated using ordinary least squares (OLS) with a correction for first-order autocorrleation. The results for both methods are similar and only the OLS results are presented here.

The coefficient estimates for sample periods ending in 1973:4, 1974:4, ..., 1978:4 are presented in Tables IX and X. All variables obtain the anticipated signs and all coefficients are significant at the .01 level. Both models also pass stability tests where the

TABLE IX

ESTIMATED MONEY SUPPLY EQUATIONS FOR SELECTED YEARS

Equation	Endpoint	UB	c	i_B/i_D	i_T	$\bar{R}^2$	SEE	D.W.	RHO
(2-16)	1973:4	1.0463 (99.28)	-.7707 (28.95)	.0230 (4.08)	-.0516 (5.29)	.9993	.0058	1.33	.79 (12.16)
(2-17)	1974:4	1.0503 (117.22)	-.7606 (34.18)	.0243 (4.16)	-.0535 (5.78)	.9994	.0061	1.37	.78 (11.85)
(2-18)	1975:4	1.0493 (137.42)	-.7632 (41.05)	.0241 (4.28)	-.0531 (6.02)	.9995	.0060	1.38	.78 (12.04)
(2-19)	1976:4	1.0505 (142.63)	-.7583 (48.17)	.0243 (4.33)	-.0548 (6.43)	.9995	.0059	1.38	.78 (12.63)
(2-20)	1977:4	1.0545 (174.71)	-.7495 (52.91)	.0243 (4.48)	-.0556 (6.59)	.9996	.0058	1.38	.78 (12.77)
(2-21)	1978:4	1.0550 (195.34)	-.7483 (60.12)	.0242 (4.55)	-.0559 (6.86)	.9997	.0057	1.41	.78 (12.97)

Note: The sample period for all equations begins with 1952:2. Values in parentheses are absolute t-values.

TABLE X

ESTIMATED DEMAND DEPOSIT EQUATIONS FOR SELECTED YEARS

Equation	Endpoint	UB	c	i_B/i_D	i_T	$\bar{R}^2$	SEE	D.W.	RHO
(2-22)	1973:4	.9821 (97.18)	-.7698 (30.17)	.0227 (4.59)	-.0336 (3.54)	.9994	.0052	1.43	.80 (13.19)
(2-23)	1974:4	.9830 (112.65)	-.7676 (35.46)	.0241 (4.64)	-.0338 (3.69)	.9995	.0054	1.47	.80 (12.81)
(2-24)	1975:4	.9777 (124.97)	-.7812 (41.08)	.0241 (4.79)	-.0320 (3.37)	.9995	.0054	1.46	.81 (13.66)
(2-25)	1976:4	.9777 (143.73)	-.7811 (48.24)	.0239 (4.87)	-.0311 (3.48)	.9996	.0052	1.45	.81 (13.95)
(2-26)	1977:4	.9798 (163.76)	-.7759 (55.29)	.0243 (5.05)	-.0325 (3.82)	.9997	.0052	1.45	.81 (13.95)
(2-27)	1978:4	.9795 (183.45)	-.7767 (63.04)	.0244 (5.12)	-.0323 (3.95)	.9997	.0051	1.49	.81 (14.10)

Note: The sample period for all equations begins with 1952:2. Values in parentheses are absolute t-values.

assumed break point is 1974:4.[11]

If the definitional explanation is correct, then equations (2-16) and (2-22) (Tables IX and X) should overpredict in post-sample simulations. This is proved by considering the two-variable money supply model:

$$M_t = \beta_1 X_t + e_t \qquad (e_t = \rho_1 e_{t-1} + w_t,\ w_t \sim N(0,\sigma_{ww})) \tag{2-28}$$

If, at time t+j, the money supply is understated, then by equation (2-10), $M_{t+j} = M'_{t+j} + a_{t+j}$. The one-step-ahead prediction error is:

$$\begin{aligned} \hat{v}_{t+j}(1) &= M'_{t+j+1} - \hat{M}'_{t+j}(1) \\ &= (M_{t+j+1} - a_{t+j+1}) - \hat{\beta}_1 X_{t+j+1} - \hat{\rho}_1 \hat{e}_{t+j} + \hat{\rho}_1 a_{t+j} \\ &= \hat{e}_{t+j}(1) - \hat{\rho}_1 \hat{e}_{t+j} - a_{t+j+1} + \hat{\rho}_1 a_{t+j} \\ &= \hat{w}_{t+j}(1) - a_{t+j+1} + \hat{\rho}_1 a_{t+j} \end{aligned} \tag{2-29}$$

Taking expectations:

$$\begin{aligned} E(\hat{v}_{t+j}(1)) &= E(\hat{w}_{t+j}(1)) - E(a_{t+j+1}) + E(\hat{\rho}_1 a_{t+j}) \\ &= 0 - a_{t+j+1} + \rho_1 a_{t+j} \\ &= -a_{t+j+1} + \rho_1 a_{t+j} \end{aligned} \tag{2-30}$$

A sufficient (but not necessary) condition for the expectation in (2-30) to be negative is that the measurement error is growing over time. This is not an unreasonable restriction.

The prediction errors from equations (2-16) and (2-22) are presented in Table XI. These results are similar to those from the time series models, in that neither equation tends to overpredict

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[11]For the money supply equation, $F(4,98) = .62$, and for the demand deposit equation, $F(4,98) = 1.02$.

TABLE XI

STATIC PREDICTION ERRORS FROM THE REGRESSION MODELS, 1974-1978

Date and Summary Statistic		Money Supply		Demand Deposits	
Year	Quarter	$Bill	|%|	$Bill	|%|
1974	1	0.3	0.1	0.4	0.2
	2	2.3	0.8	2.3	1.1
	3	2.0	0.7	1.4	1.0
	4	-4.1	1.5	-3.3	1.6
1975	1	-2.2	0.8	-0.1	0.1
	2	-0.2	0.1	0.2	0.1
	3	-0.1	0.1	-0.1	0.1
	4	0.0	0.0	-0.2	0.1
1976	1	-0.1	0.1	-0.2	0.1
	2	-0.2	0.1	-0.3	0.2
	3	0.1	0.1	-0.1	0.1
	4	1.3	0.4	0.2	0.1
1977	1	1.2	0.4	0.2	0.1
	2	0.2	0.1	-0.5	0.2
	3	1.7	0.5	1.0	0.4
	4	1.7	0.5	0.6	0.3
1978	1	-1.1	0.3	-1.5	1.0
	2	2.7	0.8	1.7	1.0
	3	1.0	0.3	-0.2	0.1
	4	-0.4	0.1	-0.3	0.1
RMSE		1.6		1.1	
Mean Error		0.3		0.1	
Mean Absolute Error		1.1		0.7	

Note: The predicted values of the money supply and demand deposits are the antilogarithms of the predicted values of ln M and ln D. The simulations use the lagged prediction error.

consistently. Where the equations do overpredict, the errors are remarkably small, with no error exceeding 1.60 percent.

Conclusions

This chapter analyzes the definitional explanation of the money demand problem. It is argued in this chapter that if the definitional explanation is correct then money supply models, as well as money demand models, should overpredict beginning in the mid-1970s.

The evidence in support of the definitional explanation is presented first. This is followed by an argument rejecting the tests of the definitional explanation on the grounds that they are ambiguous. An alternative test is then proposed. Time series and regression models of the money supply process are formed, and the conditions under which these models will overpredict (conditional upon the definitional explanation) are established. The models are estimated for the 1952-1973 period and then used to forecast money in the post-1973 period. The models track the money supply remarkably well and do not consistently overpredict in this period.

Considered jointly, the evidence from the time series and the regression models does not support the definitional explanation of the money demand problem. Rather, these findings point to the conclusion that a structural shift is the probable cause of the overpredictions of Goldfeld's (1976) money demand equation. While there may be other reasons for broadening the definition of M-1 prior to 1979, this cannot be justified on the grounds that it eliminates the prediction errors of the money demand equation.

CHAPTER III

AN ANALYSIS OF THE OMITTED VARIABLE EXPLANATION OF THE MONEY DEMAND PROBLEM

Introduction

The researchers advancing the omitted variable explanation attribute the money demand problem to the omission of an important explanatory variable from the equation. The appropriate solution, therefore, is to identify and to include the missing variable in the equation.

Just as the researchers who support the definitional explanation disagree on the proper definition of money, those who accept the omitted variable explanation do not accept one unique variable as being the missing variable in the equation. Hamburger (1977) includes a long-term interest rate and a yield on real capital (the dividend-price ratio); Friedman (1979) includes a real wealth variable; Quick and Paulus (n.d.), Porter and Mauskopf (n.d.), and Kimball (1980) add variables capturing the adoption of cash management techniques on the part of households and firms. With the exception of Porter and Mauskopf (n.d.), the above researchers present empirical evidence in support of their respective positions. Porter and Mauskopf are unable to test their hypothesis because their missing variable--business firm cash flow variance--is not available.

A Review and An Analysis of Models Supporting the Omitted Variable Expalnation

Hamburger

In his study, Hamburger (1977) argues that the money demand problem is the result of using an incorrect theoretical model of money demand. Hamburger rejects the transactions demand models of Goldfeld (1973) and Enzler et al. (1976) in favor of the more general portfolio models of Friedman (1956; 1977), Brunner and Meltzer (1963), Meltzer (1963), and Tobin (1961). The former models restrict money substitutes to a rather narrow range of short-term financial assets. These models imply that only short-term interest rates should be included among the explanatory variables in the money demand equation. The portfolio models expand the list of money substitutes to include short and long-term financial assets, real assets and physical goods. This implies that a wider range of interest rates should be included among the explanatory variables.

Hanburger's own model includes a long-term rate, a short-term rate, and the yield on real capital (the dividend-price ratio). The Hamburger model is:

$$\ln(M_t/Y_t) = \underset{(1.88)}{-.051} + \underset{(29.7)}{.890} \ln(M_{t-1}/Y_t) - \underset{(2.45)}{.022} \ln DPR - \underset{(2.39)}{.028} \ln RGB - \underset{(2.30)}{.024} \ln RSD \qquad (3\text{-}1)$$

$\bar{R}^2 = .9953$ S.E.E. = .0047 D.W. = 1.90 RHO = .52

Sample period = 1955:2-1972:4

where M_t = the nominal money supply,

Y_t = nominal GNP,

DPR_t = the dividend-price ratio

RGB_t = the long-term government bond rate, and

RSD_t = the rate on passbook savings deposits at commercial banks.

In a post-sample dynamic extrapolation (1973:1-1976:2), Hamburger's equation predicts nominal money balances rather well, with a RMSE of \$4.39 billion. The equation tends to overpredict consistently, but the errors do not become progressively larger until the first and second quarters of 1976. At this point the errors are -\$6.3 million (2.1 percent) and -\$8.9 billion (2.9 percent) respectively. Such results represent a significant improvement over those obtained by Goldfeld (1976) in his investigation of the money demand problem.

Hamburger (1977) concludes that the money demand problem is really a theoretical problem in terms of which variables to include in the money demand function. Specifically, Hamburger attributes much of the success of his model to his including DPR among the explanatory variables:

> . . . all of our tests indicate that the yield on equities (measured here as the dividend-price ratio) is an important determinant of the demand for money. Its inclusion improves the explanatory power of the function, regardless of the time period considered or the other variables in the equation . . . [S]uch results are not new, they have been reported many times before . . . and it is puzzling that those who prefer a transactions approach to the demand for money persist in ignoring them (p. 276).

Hamburger's model is re-estimated and extended using more recently revised data. The results are presented in Table XII. The first equation essentially duplicates the coefficient estimates of equation (3-1). The model shows some evidence of deterioration as the sample

TABLE XII

ESTIMATES OF HAMBURGER'S MONEY DEMAND EQUATION FOR SELECTED YEARS

Endpoint	Constant	m_{t-1}	DPR_t	RGB_t	RSD_t	$\bar{R}^2$	S.E.E.	D.W.	RHO
1972:4	-.0547	.8879	-.0173	-.0237	-.0291	.9995	.0040	1.73	.59
	(2.46)	(36.74)	(2.52)	(2.39)	(3.59)				(6.68)
1973:4	-.0465	.8941	-.0186	-.0238	-.0276	.9996	.0039	1.75	.60
	(2.24)	(38.51)	(2.78)	(2.45)	(3.50)				(6.96)
1974:4	-.0535	.8937	-.0149	-.0232	-.0266	.9996	.0039	1.78	.56
	(3.12)	(41.07)	(2.82)	(2.51)	(3.58)				(6.46)
1975:4	-.0442	.9015	-.0165	-.0221	-.0252	.9996	.0041	1.77	.53
	(2.84)	(43.13)	(3.14)	(2.37)	(3.48)				(6.11)
1976:4	-.0349	.9142	-.0162	-.0195	-.0219	.9996	.0041	1.85	.54
	(2.59)	(50.00)	(3.07)	(2.17)	(3.13)				(6.39)
1977:4	-.0347	.9140	-.0164	-.0197	-.0218	.9997	.0040	1.86	.54
	(3.14)	(55.48)	(2.29)	(3.28)	(3.25)				(6.53)
1978:4	-.0307	.9171	-.0171	-.0197	-.0208	.9997	.0041	1.81	.54
	(3.18)	(57.69)	(3.52)	(2.28)	(3.17)				(6.54)

Note: Each estimation period begins with 1952:2. Values in parentheses are absolute t-values.

period is extended (the coefficient on the lagged variable increases slightly and the RSD coefficient declines somewhat), although it does not completely break down as the Goldfeld (1976) equation does.

Static and dynamic prediction errors for the equation re-estimated through 1973:4 produce mixed results (Table XIII). So that these results may be compared with those from the Goldfeld equation, the prediction errors from the latter equation are reproduced in Table XIV. The static errors from Hamburger's re-estimated equation give no indication of a money demand problem. Even though the static simulation tends to overpredict, the errors are not consistently negative and are relatively small. This is in contrast to the static errors obtained from the Goldfeld equation. These errors are consistently negative and relatively large. The errors from the Goldfeld equation, however, stablize beyond 1975:1. Despite its satisfactory performance in the static simulation, the Hamburger equation seriously overpredicts in a dynamic simulation. Interestingly enough, the equation does not get off track until 1976:1, whereas the Goldfeld equation begins to overpredict in 1975:1. Even more interesting is the fact that the Hamburger equation passes F-tests for structural stability when the assumed breakpoints are 1974:4 ($F(5,95) = 2.88$) and 1975:4 ($F(5,95) = 1.23$).[1]

Hamburger's equation represents a substantial improvement over the Goldfeld equation in terms of post-1973 forecasting performance. Once two criticisms of Hamburger's approach are considered, his more general reformulation of the money demand equation is found to be only

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[1]Critical value at the .01 level is 3.24.

TABLE XIII

PREDICTION ERRORS FROM HAMBURGER'S MONEY DEMAND EQUATION, 1974:1-1978:4 (BILLIONS OF DOLLARS)

Date and Summary Statistics: Year	Quarter	Static Error	Dynamic Error
1974	1	1.88	1.88
	2	-1.01	1.83
	3	0.82	2.54
	4	0.69	3.52
1975	1	-2.00	1.93
	2	1.03	2.03
	3	0.64	2.64
	4	-2.96	-0.07
1976	1	-1.56	-3.13
	2	-0.10	-4.82
	3	-2.75	-8.36
	4	0.61	-9.45
1977	1	-0.50	-10.20
	2	-0.45	-10.80
	3	0.12	-10.60
	4	-0.75	-10.90
1978	1	-0.03	-10.70
	2	0.81	-9.40
	3	-1.33	-9.71
	4	-3.70	-13.30
RMSE		1.54	7.61
Mean Error		-0.53	-4.76
Mean Absolute Error		1.19	6.39

Note: These prediction errors are based upon forecasts on M_t generated by the second equation in Table XII. The forecasted value of M_t is obtained by first expressing the equation in nominal terms and then taking the antilogarithm of the predicted value of $\ln M_t$. The lagged prediction error is used in forecasting $\ln M_t$.

TABLE XIV

PREDICTION ERRORS FROM GOLDFELD'S MONEY DEMAND EQUATION, 1974:1-1978:4 (BILLIONS OF DOLLARS)

Date and Summary Statistics		Static Error	Dynamic Error
Year	Quarter		
1974	1	.87	.87
	2	-1.14	.04
	3	-.84	-1.16
	4	-1.83	-3.42
1975	1	-4.25	-8.40
	2	-1.62	-11.60
	3	-1.78	-13.90
	4	-5.64	-19.50
1976	1	-4.26	-24.90
	2	-2.70	-28.10
	3	-5.42	-32.90
	4	-3.12	-35.70
1977	1	-4.74	-39.20
	2	-4.46	-42.40
	3	-3.39	-44.10
	4	-4.35	-45.90
1978	1	-4.50	-47.80
	2	-3.50	-48.70
	3	-4.76	-50.30
	4	-7.38	-54.60
RMSE		3.93	33.25
Mean Error		-3.44	-27.58
Mean Absolute Error		3.53	27.67

marginally superior to the Goldfeld equation. As seen in equation (3-1), Hamburger constrains the long-run income elasticity of money demand to be unity. Empirical studies that freely estimate this elasticity place it closer to .60 (Goldfeld, 1973, 1976; Hein and Hafer, 1980; and Table I of this study). Also, just as Hamburger criticizes others for not including a long-term interest rate in their models, he may equally be criticized for not including a short-term rate (other than the rate on savings deposits) in his model.

Hamburger's model is re-estimated where the long-run income elasticity is left unconstrained. This equation is:

$$\begin{aligned} \ln m_t = {} & b_0 + b_1 \ln m_{t-1} + b_2 \ln y_t + b_3 \ln DPR_t + \\ & b_4 \ln RGB_t + b_5 \ln RSD_t \end{aligned} \qquad (3\text{-}2)$$

where $m_t = M_t/P_t \cdot N_t$ = real, per-capita balances demanded,

M_t = the nominal demand for money,

P_t = the GNP deflator,

N_t = population, and

$m_{t-1} = M_{t-1}/P_t \cdot N_{t-1}$.

All other variables are as previously defined.

The results from estimating (3-2) for various years are presented in Table XV. While the model does not completely break down as the sample period is extended, it does exhibit a pattern similar to that found in the Goldfeld model. The speed of adjustment coefficient declines significantly from .2427 (1 - .7573), to .0870 (1 - .9130). The long-run income elasticity approaches one (as is hypothesized in the Hamburger framework) as the sample is extended, but this occurs as a result of the relatively large decline in the speed of adjustment

TABLE XV

ESTIMATES OF EQUATION (3-2) FOR SELECTED YEARS

Endpoint	Constant	m_{t-1}	y_t	DPR_t	RGB_t	RSD_t	$\bar{R}^2$	S.E.E.	D.W.	RHO
1973:4	-.0427 (1.80)	.7573 (11.75)	.1338 (5.06)	-.0185 (2.66)	-.0250 (2.43)	-.0500 (3.80)	.9960	.0039	1.68	.67 (8.42)
1974:4	-.0484 (2.34)	.7752 (13.57)	.1324 (5.39)	-.0174 (3.09)	-.0248 (2.52)	-.0472 (3.83)	.9959	.0039	1.74	.63 (7.78)
1975:4	-.0476 (2.44)	.8584 (18.00)	.1116 (4.92)	-.0179 (3.17)	-.0241 (2.44)	-.0323 (2.99)	.9959	.0041	1.74	.59 (7.00)
1976:4	-.0429 (2.26)	.8992 (22.94)	.0942 (4.88)	-.0169 (3.00)	-.0211 (2.21)	-.0238 (2.53)	.9962	.0042	1.83	.58 (7.00)
1977:4	-.0422 (2.37)	.9023 (25.29)	.0932 (5.32)	-.0172 (3.21)	-.0211 (2.29)	-.0232 (2.63)	.9965	.0041	1.84	.57 (7.09)
1978:4	-.0401 (2.32)	.9130 (27.00)	.0894 (5.30)	-.0176 (3.36)	-.0212 (2.31)	-.0208 (2.46)	.9966	.0042	1.79	.56 (6.96)

Note: Each estimation period begins with 1952:2. Values in parentheses are absolute t-values.

coefficient.[2] For the sample periods ending in 1973:4 and 1974:4, the long-run income elasticities are closer to one-half as implied by the standard inventory model.[3] It appears that it would be more appropriate for Hamburger to estimate his equation with the long-run income elasticity left unconstrained.

The static and dynamic simulation results from (3-2) more closely resemble those obtained from the Goldfeld equation. The prediction errors from the first equation in Table XV are presented in Table XVI. Unlike equation (3-1), but like the Goldfeld equation, the pattern of errors suggests that a structural shift occurs in 1975:1. The errors stabilize beyond 1975:1 until 1978:4, when another shift probably occurs. In the dynamic simulation equation (3-2) proves to be superior to the Goldfeld equation, but the errors are significantly larger than those obtained from the original Hamburger equation. Beginning in 1975:1, the errors from (3-2) are negative and grow over time. An F-test leads to the rejection of the null hypothesis of structural stability when the assumed breakpoint is 1974:4 ($F(6,93) = 3.45$).

Further analysis reveals that Hamburger's model is misspecified in terms of the interest rates. When a short-term interest rate (the commercial paper rate) is added to equation (3-2), this variable is significant, but the long-term bond rate is no longer significant

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[2]For example, by 1978:4, the long-run income elasticity is 1.03, [.0894/(1-.9130)], but the speed of adjustment coefficient decreases from .2427 to .0870 between 1973:4 and 1978:4.

[3]These elasticity are .55 [.1338/(1-.7573)] and .59 [.1324/(1-.7752)].

[4]This apparent shift coincides with the nationwide introduction of ATS accounts.

TABLE XVI

PREDICTION ERRORS FROM EQUATION (3-2), 1974:1-1978:4
(BILLIONS OF DOLLARS)

Date and Summary Statistics: Year	Quarter	Static Error	Dynamic Error
1974	1	1.97	1.97
	2	-1.32	1.53
	3	.09	1.28
	4	-.34	.72
1975	1	-2.84	-2.47
	2	-.02	-3.98
	3	-.66	-5.16
	4	-3.88	-9.30
1976	1	-2.55	-13.40
	2	-.96	-15.60
	3	-3.75	-19.50
	4	-.57	-20.70
1977	1	-1.61	-21.60
	2	-1.79	-22.30
	3	-1.15	-22.30
	4	-1.94	-22.70
1978	1	-1.09	-22.30
	2	-1.15	-21.80
	3	-2.95	-23.00
	4	-5.53	-27.50
RMSE		2.28	16.74
Mean Error		-1.60	-13.40
Mean Absolute Error		1.81	13.95

Note: These prediction errors are based upon forecasts of M_t generated by the first equation in Table XV. The forecasted value of M_t is obtained by first expressing the equation in nominal terms and then taking the antilogarithm of the predicted value of $\ln M_t$. The lagged prediction error is used in forecasting $\ln M_t$.

(sample period = 1952-1973). The dividend-price ratio, however, remains significant. This suggests that it is more appropriate to enter DPR into Goldfeld's equation. According to Hamburger, the addition of DPR to any model should improve the predictive performance of the model. When DPR is added to Goldfeld's model this variable is significant, but SEE shows little change. Furthermore, the equation deteriorates as badly as the Goldfeld equation (without DPR) when the sample period is extended. These findings are presented in Table XVII.

The evidence from the present analysis indicates the apparent success of Hamburger's approach is the result of (1) constraining the long-run income elasticity of money demand to be unity and (2) including DPR in the equation along with a long-term interest rate (while omitting a short-term rate). When the income elasticity constraint is relaxed, Hamburger's model is found only to be marginally superior to the Goldfeld equation. The overpredictions are not eliminated, and the equation is found to be structurally unstable. When a short-term rate is included in the equation, Hamburger's model proves to be as unsatisfactory as Goldfeld's model.

Hamburger argues that a more general model of money demand will explain the overpredictions of money demand that surface in the mid-1970s. He presents a model that seemingly supports this point of view. This section analyzes Hamburger's equation, and while the evidence presented above does not rule out the possibility that a more general model will eliminate the prediction errors, the evidence does question the validity of Hamburger's own model.

TABLE XVII

ESTIMATES OF THE GOLDFELD MONEY DEMAND EQUATION WITH THE DIVIDEND-PRICE RATIO AS AN INCLUDED EXPLANATORY VARIABLE

Endpoint	Constant	m_{t-1}	y_t	RCP_t	RTD_t	DPR_t	$\bar{R}^2$	S.E.E.	D.W.	RHO
1973:4	-.0756	.8275	.1238	-.0151	-.0382	-.0119	.9965	.0035	1.83	.56
	(4.21)	(14.82)	(6.54)	(5.32)	(3.29)	(1.98)				(6.22)
1974:4	-.0782	.8416	.1218	-.0153	-.0355	-.0114	.9966	.0035	1.86	.53
	(4.95)	(17.55)	(7.17)	(5.64)	(3.32)	(2.42)				(5.99)
1975:4	-.0687	.9489	.0886	-.0129	-.0257	-.0132	.9962	.0039	1.81	.46
	(4.59)	(24.46)	(6.16)	(4.69)	(1.67)	(2.77)				(4.98)
1976:4	-.0643	.9894	.0731	-.0120	-.0067	-.0122	.9964	.0040	1.91	.45
	(4.32)	(30.05)	(6.06)	(4.39)	(.81)	(2.53)				(5.04)
1977:4	-.0608	1.0000	.0664	-.0114	-.0034	-.0124	.9967	.0039	1.92	.43
	(4.44)	(33.79)	(6.57)	(4.36)	(.46)	(2.67)				(4.87)
1978:4	-.0615	.9952	.0673	-.0116	-.0041	-.0108	.9967	.0039	1.89	.45
	(4.36)	(33.91)	(6.55)	(4.42)	(.54)	(2.38)				(5.19)

Note: Each estimation period begins with 1952:2. Values in parentheses are absolute t-values.

Friedman

Friedman (1979) agrees that the dividend-price ratio (DPR) is in fact the crucial feature of Hamburger's model because it acts as a proxy for a real household wealth variable. However, Friedman argues that a wealth variable should replace DPR in Hamburger's model. Friedman arrives at this conclusion when he notes most of the variation in DPR over time is due to the variation in equity prices, which in turn accounts for most of the variation in household wealth. The time series behavior of DPR serves as a proxy for the time series behavior of household wealth, and according to Friedman, DPR should be replaced by a wealth variable. In arguing that a wealth variable should be entered directly into the Hamburger equation, Friedman revives an old debate in monetary economics.[5]

To test his proposition, Friedman re-estimates Hamburger's equation using a wealth variable--household financial assets--in the place of DPR. These estimation results are:

$$\begin{aligned} \ln (M_t/Y_t) = & \underset{(4.88)}{-.1062} + \underset{(22.64)}{.9450} \ln (M_{t-1}/Y_t) + \underset{(2.00)}{.0345} \ln W_t - \\ & \underset{(2.54)}{.0284} \ln RGB_t - \underset{(2.02)}{.0180} \ln RSD_t \end{aligned} \tag{3-3}$$

$\bar{R}^2 = .9966$ S.E.E. = .0048 D.W. = 2.00

Sample period = 1952:2-1972:4

where W_t = household financial assets, and
all other variables are as previously defined.

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[5]See Boorman and Havrilesky (1973) and Laidler (1977).

In a post-sample dynamic simulation, equation (3-3) tracks actual money balances relatively well. In fact, the equation tends to overpredict an average. These simulation results are presented in Table XVIII. The pattern of the errors is interesting in that the equation overpredicts until 1975 and then underpredicts thereafter (with the exception of 1976:4).

Friedman's equation is re-estimated and extended using more recently revised data. These estimation results are seen in Table XIX. The results are significantly different from those obtained by Friedman. While Friedman finds the wealth variable to be significant in his equation, the results in Table XIX show the wealth variable is not significant until the 1976 observations are included in the sample. This can only be due to data revisions, since the only differences in the data are in the revised income and money data series. Otherwise, the data sets are the same.[6] Even where the wealth variable is significant in Table XIX, the speed of adjustment coefficient is relatively small (less than 10 percent) and tends to decrease as the sample period is extended. Friedman's equation is re-estimated using household net worth as the wealth variable, and this variable is not significant until the 1975 observations are included. This equation also deteriorates badly in terms of the speed of adjustment coefficient as the sample period is extended (Table XX).

The evidence in Tables XIX and XX suggests Friedman's approach does not represent the solution to the money demand problem. Since Friedman attempts to explain the money demand problem within

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[6]The Cochrane-Orcutt estimation technique is used in both cases.

TABLE XVIII

PREDICTION ERRORS FROM FRIEDMAN'S MONEY DEMAND EQUATION, 1973:1-1977:4 (BILLIONS OF DOLLARS)

Date and Summary Statistics: Date	Date and Summary Statistics: Quarter	Dynamic Error
1973	1	-2.65
	2	-1.08
	3	-3.53
	4	-1.69
1974	1	-0.89
	2	-0.25
	3	0.56
	4	1.26
1975	1	1.02
	2	4.33
	3	3.29
	4	1.99
1976	1	2.57
	2	0.96
	3	0.15
	4	-0.50
1977	1	0.37
	2	0.26
	3	1.30
	4	0.79
RMSE		1.89
Mean Error		0.41

Source: Friedman (1979).

TABLE XIX

ESTIMATES OF FRIEDMAN'S MONEY DEMAND EQUATION WHERE WEALTH IS DEFINED AS HOUSEHOLD FINANCIAL ASSETS

Endpoint	Constant	m_{t-1}	W_t	RGL_t	RSD_t	$\bar{R}^2$	S.E.E.	D.W.	RHO
1972:4	-.0818 (3.10)	.8857 (28.16)	.0014 (0.11)	-.0274 (2.70)	-.0226 (2.94)	.9995	.0041	1.68	.56 (6.16)
1973:4	-.0674 (2.99)	.9012 (32.32)	.0056 (0.51)	-.0259 (2.65)	-.0206 (2.82)	.9995	.0041	1.70	.55 (6.06)
1974:4	-.0576 (3.12)	.9119 (37.02)	.0107 (1.20)	-.0248 (2.64)	-.0202 (2.92)	.9995	.0041	1.75	.52 (5.77)
1975:4	-.0468 (2.94)	.9242 (41.41)	.0136 (1.66)	-.0231 (2.47)	-.0185 (2.75)	.9995	.0043	1.74	.48 (5.35)
1976:4	-.0374 (2.96)	.9365 (51.69)	.0159 (2.04)	-.0202 (2.32)	-.0167 (2.58)	.9996	.0043	1.81	.48 (5.35)
1977:3[a]	-.0366 (3.43)	.9374 (59.38)	.0161 (2.16)	-.0201 (2.42)	-.0165 (2.66)	.9996	.0042	1.82	.47 (5.41)

[a]The household financial assets series was provided by Friedman (1979) and was available through 1977:3.

TABLE XX

ESTIMATES OF FRIEDMAN'S MONEY DEMAND EQUATION WHERE WEALTH IS DEFINED AS HOUSEHOLD NET WORTH

Endpoint	Constant	m_{t-1}	W_t	RGL_t	RSD_t	$\bar{R}^2$	S.E.E.	D.W.	RHO
1972:4	-.0707 (3.36)	.9152 (26.04)	.0323 (1.22)	-.0274 (2.81)	-.0253 (3.21)	.9995	.0041	1.72	.56 (6.17)
1973:4	-.0641 (3.17)	.9192 (26.67)	.0278 (1.07)	-.0275 (2.87)	-.0224 (2.95)	.9995	.0041	1.72	.56 (6.33)
1974:4	-.0593 (3.30)	.9272 (30.07)	.0347 (1.51)	-.0283 (3.08)	-.0221 (2.99)	.9996	.0041	1.78	.55 (6.28)
1975:4	-.0489 (3.07)	.9442 (33.49)	.0448 (2.04)	-.0276 (2.97)	-.0211 (2.90)	.9996	.0042	1.78	.53 (5.99)
1976:4	-.0383 (2.78)	.9583 (37.26)	.0446 (2.02)	-.0244 (2.73)	-.0175 (2.54)	.9996	.0042	1.85	.53 (6.22)
1977:4	-.0350 (3.07)	.9633 (42.98)	.0466 (2.21)	-.0240 (2.78)	-.0167 (2.56)	.9996	.0042	1.85	.53 (6.27)
1978:4	-.0298 (3.01)	.9691 (46.18)	.0471 (2.27)	-.0241 (2.80)	-.0145 (2.30)	.9997	.0042	1.80	.51 (6.16)

Hamburger's (1977) framework, the same criticisms that are applied to Hamburger's model (the choice of interest rates and the constrained income elasticity) may also be directed toward Friedman's model. Also, the coefficient on the lagged dependent variable in Friedman's (1979) own equation, (3-3), indicates a slow speed of adjustment to equilibrium in money holdings. Statistically speaking, the coefficient is not significantly different from unity which implies equilibrium is never reached and long-run elasticities are undefined.

Friedman's model is re-estimated where the long-run income elasticity is left unconstrained. The equation is:

$$\ln m_t = b_0 + b_1 \ln m_{t-1} + b_2 \ln y_t + b_3 \ln W_t + b_4 \ln RGB_t + b_5 \ln RSD_t \tag{3-4}$$

When equation (3-4) is estimated, the wealth variable--household financial assets--is never significant (Table XXI). In addition, the coefficient on the lagged dependent variable tends to increase over time and is relatively large by 1977:3 (.9369). The coefficient on the real income variable tends to decline over time, while the coefficient on the RSD variable is no longer significant by 1976. When the household financial asset variable is replaced by net worth, no dramatic changes occur in the estimation results (Table XXII).

Even though the question is whether to include wealth and not whether to exclude income, the Goldfeld (1976) equation is estimated where wealth serves as the only constraint. Wealth is always significant, but once again, there is no significant improvement in the estimation results.

TABLE XXI

ESTIMATES OF EQUATION (3-4) WHERE WEALTH IS DEFINED AS HOUSEHOLD FINANCIAL ASSETS

Endpoint	Constant	m_{t-1}	y_t	W_t	RGL_t	RSD_t	$\bar{R}^2$	S.E.E.	D.W.	RHO
1973:4	-.0811	.7397	.1445	-.0009	-.0291	-.0466	.9956	.0041	1.59	.60
	(1.09)	(10.71)	(4.81)	(0.07)	(2.84)	(3.46)				(7.04)
1974:4	-.0158	.8142	.1179	.0100	-.0278	-.0355	.9955	-.0041	1.68	.56
	(0.26)	(13.78)	(4.49)	(1.03)	(2.79)	(2.91)				(6.46)
1975:4	.0086	.8983	.0913	.0138	-.0252	-.0208	.9956	.0043	1.71	.51
	(0.15)	(19.29)	(4.02)	(1.47)	(2.56)	(2.00)				(5.77)
1976:4	.0224	.9327	.0759	.0155	-.0217	-.0148	.9959	.0043	1.79	.49
	(0.41)	(25.42)	(4.17)	(1.70)	(2.36)	(1.63)				(5.57)
1977:3[a]	.0237	.9369	.0743	.0156	-.0215	-.0140	.9962	.0043	1.80	.49
	(0.45)	(28.39)	(4.55)	(1.76)	(2.43)	(1.65)				(5.59)

[a]The household financial assets series was provided by Friedman (1979) and was available through 1977:3.

TABLE XXII

ESTIMATES OF EQUATION (3-4) WHERE WEALTH IS DEFINED AS HOUSEHOLD NET WORTH

Endpoint	Constant	m_{t-1}	y_t	W_t	RGL_t	RSD_t	$\bar{R}^2$	S.E.E.	D.W.	RHO
1973:4	.2184 (1.38)	.7561 (11.53)	.1097 (3.43)	.0569 (1.86)	-.0289 (2.85)	-.0514 (3.82)	.9958	.0040	1.66	.65 (7.86)
1974:4	.2855 (1.97)	.7910 (13.65)	.0956 (3.33)	.0699 (2.50)	-.0302 (3.07)	-.0465 (3.65)	.9958	.0040	1.74	.64 (7.87)
1975:4	.3183 (2.15)	.8682 (17.77)	.0727 (2.67)	.0761 (2.66)	-.0300 (2.98)	-.0330 (2.89)	.9958	.0042	1.75	.61 (7.52)
1976:4	.2467 (1.70)	.9238 (22.90)	.0568 (2.23)	.0606 (2.17)	-.0257 (2.63)	-.0198 (2.08)	.9960	.0043	1.83	.60 (7.40)
1977:4	.2500 (1.78)	.9402 (26.66)	.0503 (2.19)	.0608 (2.24)	-.0250 (2.65)	-.0164 (1.92)	.9963	.0042	1.84	.58 (7.28)
1978:4	.2156 (1.57)	.9625 (30.40)	.0469 (2.16)	.0538 (2.02)	-.0253 (2.74)	-.0103 (1.34)	.9964	.0043	1.78	.55 (6.72)

The omitted variable explanation may be correct, and wealth may indeed be the appropriate missing variable. The evidence in this section, however, does not provide support for wealth as the missing variable, at least not within the framework of the Hamburger and Goldfeld models.

Quick and Paulus

Quick and Paulus (n.d.) argue that high interest rates in the mid-1970s lead to the development of new cash management techniques and to their subsequent adoption by households and firms. The net effect of these events is to reduce the brokerage fee in the standard inventory-theoretic model of money demand:

$$M^* = (2bT/r)^{\frac{1}{2}} \qquad (3\text{-}5)$$

where M^* = desired money holdings,

T = income or the total number of transactions over the period,

b = the brokerage fee or transactions costs, and

r = the rate of interest.

From (3-5) it is seen that if the brokerage fee declines, then money holders reduce M^*, and the demand for money function shifts downward.

In empirical models of money demand the brokerage fee is usually assumed to be constant and is impounded into the constant term of the function. Quick and Paulus argue that such a simplification poses no problem until the mid-1970s when it becomes more appropriate to include the brokerage fee among the explanatory variables.

Quick and Paulus believe the primary determinant of the rate of cash management innovation (and therefore the primary determinant of the variability of b) is the level of interest rates. Individuals and firms are assumed to have threshold rates of interest, and if these threshold rates are penetrated from below money holders adopt new cash management techniques. This adoption process leads to permanent increases in velocity.[7] If interest rates move still higher, other threshold rates are penetarted leading to further adoptions of cash management tools.[8] If interest rates fall, cash management tools are not necessarily scrapped if the revenue from using them exceeds the marginal cost.

Quick and Paulus attempt to model the rate at which cash management services are either adopted or scrapped. This is done by including a threshold interest rate variable in the money demand equation. The approach is not unlike that taken by Duensenberry (1949) in his reformulation of the consumption function. The Quick and Paulus (n.d.) model is:

$$\begin{aligned} \ln d_t = {} & a_0 + a_1 \ln y_t + a_2 \ln d_{t-1} + a_3 \ln RCP_t + \\ & a_4 \ln RTD_t + a_5 \ln RCPM_t \end{aligned} \qquad (3\text{-}6)$$

where $d_t = D_t/P_t$ = real demand deposit balances demanded,

D_t = nominal demand deposits demanded,

$d_{t-1} = (D_{t-1}/P_{t-1})$,

$RCPM_t$ = the adjusted peak commercial paper rate, and all other variables are as previously defined.

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[7]This idea is not new. Minsky (1957) made a similar point some 20 years earlier.

[8]As an individual's threshold rate is penetrated from below, a new and higher threshold rate is established. Hence, if interest rates move high enough, old as well as new participants are drawn into the cash management process.

$RCPM_t$ is defined as $\max(RCP_t, RCPM_{t-1} * (RCP_t/RCPM_{t-1})^{\alpha})$. If RCP_t is greater than $RCPM_{t-1}$ (last period's threshold rate) then $RCPM_t = RCP_t$. If RCP_t is less than $RCPM_{t-1}$, then $RCPM_t = RCPM_{t-1}$ multiplied by a decay factor. For $\alpha = 0$, there is no scrapping of cash management techniques as interest rates fall; for $\alpha = 1$, $RCPM_t = RCP_t$ which implies that cash management tools are immediately scrapped. Quick and Paulus estimate their model for values of α that range from 0 to .10 and find their model to be quite robust for changes in α. Quick and Paulus report results for $\alpha = .05$, and these are found in Table XXIII.

For the first equation in Table XXIII, the sample period ends before the presumed breakdown in money demand. As would be expected, the $RCPM_t$ variable is not significant. However, when the 1974 and 1975 observations are included (the last two equations in the table), the $RCPM_t$ variable obtains statistical significance.

Quick and Paulus use the second equation in Table XXIII to predict deposits in a brief post-sample simulation (1975:1-1975:3). The respective errors are -$.90 billion, $0 and -$2.4 billion. Although the prediction errors are relatively small, it is difficult to make a judgment regarding the predictive performance of this model based on three forecasts.

A policy moral drawn by Quick and Paulus from their model is if the monetary authorities seek to smooth out short-run variability in interest rates, pressure may accumulate which could result in overall wider swings in interest rates over time. This means that threshold rates will be penetrated more often, leading to further adoptions of cash management techniques. The result will be futher, unpredictable

TABLE XXIII

THE QUICK AND PAULUS MONEY DEMAND EQUATION FOR SELECTED YEARS

Period	Constant	y_t	d_{t-1}	RCP_t	RTD_t	$RCPM_t$	S.E.E.	D.W.
1952: -1974:1	-1.3	.24	.58	-.026	-.051	-.0019	.0055	.30
	(7.3)	(7.3)	(8.6)	(6.7)	(5.1)	(1.8)		(2.90)
1952:2-1974:4	-1.3	.24	.63	-.022	-.046	-.0050	.0063	.45
	(6.0)	(6.1)	(8.1)	(4.5)	(3.8)	(4.2)		(4.80)
1952:2-1975:3	-1.0	.18	.75	-.021	-.030	-.0048	.0068	.31
	(5.2)	(5.3)	(11.6)	(4.7)	(2.9)	(4.5)		(3.20)

Source: Quick and Paulus (n.d.), p. 15.

shifts in money demand in the future unless future rates of adoption of cash management techniques are estimated.

Despite the fact that the Quick and Paulus model appears to explain the overpredictions of money in the 1974-1975 period, one must be concerned about the declines that occur in the y_t and RTD_t coefficients, and the rather significant increase that takes place in the d_{t-1} coefficient over the three sample periods. The behavior of these coefficients is similar to the pattern that is found in the Goldfeld (1976) equation as it is breaking down. One may therefore legitimately question whether or not the Quick and Paulus (n.d.) model itself will deteriorate if additional observations are added to the sample period.

An implication of the Quick and Paulus model allows their model to be analyzed further. Quick and Paulus assume that the rate of development of cash management tools is a function of the level of interest rates. They also state that if interest rates fall below their past peak and remain there, then "we would expect the normal inventory-theoretic relationships between money, interest, and income to prevail without any major shifts in these relationships due to radical cash management innovation" (p. 12).

Interest rates peaked in 1974:3 and never again penetrated those peaks until the very end of the sample period under consideration in this study. For the Quick and Paulus model, this implies a one-time shift[9] takes place in the money demand function between 1974 and 1978. The pattern of the static prediction errors from the Goldfeld (1976)

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[9]Defined here as a shift occurring over a period of a few quarters rather than as an abrupt shift occurring in just one quarter.

equation seems to confirm this implication (Table XIV). The pattern suggests a single shift occurs in the 1974:2-1975:1 period. In terms of the Quick and Paulus model (n.d.), this implies the money demand function experiences a one-time downward shift in this period due to a one-time reduction in the brokerage fee (b).

Unfortunately, an extension of Quick and Paulus' results does not support this implication of their model. These results are presented in Table XXIV. First of all, when the sample period is terminated at 1973:4, the coefficient on RCPM, as expected, is not significant. It is with the addition of the observations in 1974 and 1975 that the RCPM variable becomes significant. Nevertheless, as the sample period is extended the equation begins to deteriorate in terms of the other variables. By 1978 the coefficient on the lagged dependent variable is an implausible 1.03; the short-term income elasticity declines by over 50 percent; the RTD and RCPM variables are no longer significant.

Under the assumption of a single shift in the function, another test of the Quick and Paulus model is possible. Since Quick and Paulus assume the brokerage fee is impounded in the constant term, a one-time shift implies a one-time reduction in the constant term. This possibility is analyzed using a dummy variable model of the form:

$$\begin{aligned} \ln m_t = b_0 + b_1 D_1 + b_2 \ln m_{t-1} + b_3 \ln y_t + \\ b_4 \ln RTP_t + b_5 \ln RTD_t \end{aligned} \tag{3-7}$$

where D_1 = a dummy variable such that $D_1 = 1$ for time periods beyond 1974:4, elsewhere $D_1 = 0$.

The dummy variable is given a value of unity starting in 1975:1 since the static errors from the Goldfeld (1976) equation indicate the possibility of a major shift at that point.

TABLE XXIV

ESTIMATES OF THE QUICK AND PAULUS MODEL FOR SELECTED YEARS

Endpoint	Constant	m_{t-1}	y_t	RCP_t	RTD_t	$RCPM_t$	$\bar{R}^2$	S.E.E.	D.W.	RHO
1973:4	-.1091	.8000	.1433	-.0140	-.0389	-.0014	.9967	.0036	1.81	.48
	(6.88)	(14.46)	(6.86)	(4.78)	(3.35)	(1.69)				(5.07)
1974:4	-.1114	.8824	.1397	-.0140	-.0344	-.0016	.9967	.0035	1.84	.46
	(7.30)	(16.02)	(6.86)	(4.91)	(3.20)	(2.14)				(4.98)
1975:4	-.1062	.9263	.1086	-.0115	-.0140	-.0019	.9964	.0039	1.79	.44
	(6.67)	(20.80)	(5.62)	(3.86)	(1.47)	(2.38)				(4.70)
1976:4	-.0944	.9848	.0835	-.0111	-.0018	-.0014	.9965	.0041	1.89	.45
	(5.99)	(26.79)	(5.15)	(3.60)	(.22)	(1.80)				(5.01)
1977:4	-.0810	1.0326	.0599	-.0117	.0088	-.0006	.9967	.0040	1.90	.41
	(6.07)	(36.52)	(5.41)	(4.00)	(1.45)	(.99)				(4.54)
1978:4	-.0827	1.0250	.0633	-.0114	.0075	-.0009	.9968	.0040	1.88	.41
	(6.22)	(40.57)	(6.04)	(4.12)	(1.39)	(1.38)				(4.67)

Note: Each estimation period begins with 1952:2. Values in parentheses are absolute t-values.

Under the assumption of a single reduction in the brokerage fee, the dummy variable model should explain variations in money demand beyond 1974:4 relatively well. The results of estimating equation (3-7) for various sample periods are found in Table XXV. The dummy variable is always significant and always obtains the expected negative sign. While the equation does not completely break down as the sample period is extended, the coefficients on m_{t-1}, y_t and RTD_t show some evidence of deterioration. Table XXVI reveals that in a post-sample static simulation for the 1976-1978 period, the dummy variable model significantly outperforms the Goldfeld (1976) equation. (The mean absolute error is reduced by approximately 60 percent over the same 1976-1978 period.) On the other hand, the dummy variable model does not completely eliminate the overpredictions of money.

The dummy variable model of equation (3-7) provides some evidence to indicate that a one-time reduction in the constant term of the money demand model explains a portion of the overpredictions. Whether this one-time reduction in the constant term is due to a reduction in the brokerage fee as the Quick and Paulus (n.d.) model implies, cannot be determined. Even though the dummy variable model does not completely eliminate the tendency for the model to overpredict, it significantly reduces the static errors obtained from the Goldfeld (1976) equation. This suggests that other cash management variables should be considered in conjunction with an assumed reduction in the brokerage fee. At the same time, the analysis rejects the specific form of the Quick and Paulus (n.d.) model.

TABLE XXV

ESTIMATES OF THE GOLDFELD MONEY DEMAND EQUATION WITH A DUMMY INTERCEPT TERM

Endpoint	Constant	m_{t-1}	y_t	RCP_t	RTD_t	D_1	$\bar{R}^2$	S.E.E.	D.W.	RHO
1975:4	-.0924	.8763	.1103	-.0165	-.0235	-.0143	.9967	.0037	1.76	.46
	(6.93)	(19.37)	(6.94)	(6.33)	(2.45)	(3.83)				(5.00)
1976:4	-.0892	.8933	.1031	-.0159	-.0198	-.0151	.9969	.0038	1.83	.45
	(6.88)	(21.03)	(7.08)	(6.23)	(2.21)	(4.10)				(4.99)
1977:4	-.0878	.9017	.0996	-.0156	-.0180	-.0151	.9972	.0037	1.84	.44
	(7.07)	(22.55)	(7.44)	(6.32)	(2.15)	(4.16)				(4.99)
1978:4	-.0880	.9104	.0979	-.0163	-.0156	-.0151	.9973	.0037	1.82	.43
	(7.20)	(24.07)	(7.86)	(6.75)	(2.03)	(4.18)				(4.96)

Note: Each estimation period begins with 1952:2. Values in parentheses are absolute t-values.

TABLE XXVI

STATIC PREDICTION ERRORS FROM EQUATION (3-7)

Date and Summary Statistics: Year	Quarter	Static Error ($Bill)
1976	1	-2.38
	2	-.98
	3	-2.95
	4	-1.50
1977	1	-3.67
	2	-4.00
	3	-2.67
	4	-3.37
1978	1	-.42
	2	1.17
	3	.18
	4	-2.21
RMSE		2.45
Mean Error		-1.90
Mean Absolute Error		2.13

Porter and Mauskopf

Porter and Mauskopf (n.d.) also attribute the money demand problem to recent developments in cash management tools. They develop this argument within the Miller-Orr (1966) model of the firm's demand for money. The Miller-Orr model is:

$$M^* = 4/3(3b\sigma^2/4r)^{1/3} \tag{3-8}$$

where M^* = desired money holdings,

r = the rate of interest, and

σ^2 = the variance of the firm's daily cash flow.

In the Miller-Orr model σ^2, rather than income, serves as the transactions variable. According to Porter and Mauskopf (n.d.), traditional models of money demand are misspecified since they only include income as the transactions variable. However, as long as the relationship between the firm's daily cash flow variance and income (σ^2/y) remains proportional (in the aggregate), no serious misspecification problem occurs.

According to Porter and Mauskopf (n.d.), the money demand problem occurred because the σ^2/y ratio did not remain stable in the mid-1970s. In particular, the cash flow variance term declined as firms purchased cash management tools and services.[10] The purchase of cash management

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[10]These services and techniques included lock boxes, remote disbursement, cash concentration accounts (aided by the use of wire services), and cash balance forecasting methods. When a firm purchases lock box services from a bank, the bank informs the firm on, say, a daily basis as to what receipts are considered to be collected balances. In remote disbursement the firm maintains a fixed balance account in a relatively remote bank which receives only one cash letter from the Federal Reserve each day. If the letter is received early in the day the firm is able to determine the amount of funds needed to cover all claims against its account for that day. In a cash concentration system a firm wires excess demand deposit balances from its various collection accounts to a central account. This system allows a firm to take advantage of the economies of scale associated with operating one account instead of many separated accounts. The optimal amount of cash balances in the consolidated account is less than the sum total of optimal cash balances in the separate accounts. The effects of these cash management techniques are that the firm is better able to determine the amount of funds available for financial investment (lock boxes and remote disbursement accounts) and the fixed costs of making financial investments are reduced since funds are not disbursed from many individual accounts (cash concentration accounts). Additional details concerning these services are found in Porter and Mauskopf (n.d.).

methods was itself a response to the relatively high interest rates that prevailed in 1974. Given the decline in the σ^2/y ratio, money demand models that continued to use real income as the only transactions variable were bound to overpredict. On the other hand, money demand models that included a measure of σ^2 as a transactions variable would not have overpredicted money demand in the mid-1970s. Porter and Mauskopf also noted that reductions in the brokerage fee probably contributed to the reduction in the demand for money, but they considered the decline in σ^2 as the more important source of the reduction. Unfortunately, Porter and Mauskopf could not test their explanation since they had no observations on business firm cash flow variance.

An indirect test of the Porter and Mauskopf hypothesis is possible under the assumption of a single shift in the money demand function.[11] This assumption is not implausible. By the Porter-Mauskopf explanation, the widespread adoption of cash management services is the result of the relatively high interest rates of 1974. Since interest rates subsequently fell and did not again penetrate the peaks of 1974,[12] the adoption of cash management services in 1974 and 1975 is considered to be a one-time event. In terms of the Porter-Mauskopf model, this assumption implies single reduction in the σ^2/y ratio and the brokerage fee. In terms of the Goldfeld equation, this implies single reductions in the constant term and the short-run income elasticity of money demand.

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[11]See footnote 9.

[12]The sample period in this study terminates with 1978:4. Interest rates actually penetrate their 1974 peaks at the very end of the sample period.

These possibilities are tested using the dummy variable model:

$$\ln m_t = b_0 + b_1 D_1 + b_2 \ln m_{t-1} + b_3 \ln y_t + b_4 \ln Z_t + b_5 \ln RCP_t + b_6 \ln RTD_t \tag{3-9}$$

where D_1 = a dummy variable such that $D_1 = 1$ for time periods beyond 1974:4; otherwise, $D_1 = 0$, and

$Z_t = D_1 \ln (y_t)$.

D_1 is included to capture the reduction in the brokerage fee, and Z_t is included to capture the one-time reduction in the short-run income elasticity that occurs if the σ^2/y ratio declines.

Equation (3-9) is estimated for selected sample periods, and these results are found in Table XXVII. By 1977, b_1 and b_4 enter the equation significantly, but only b_4 has the expected negative sign. Strangely enough, the b_1 coefficient implies a net increase in the constant term rather than a net decrease. It is not clear why this occurs. These results provide general support for the Porter and Mauskopf argument since the change in the y_t coefficient is significant and is of the correct sign. Apparently, a significant portion of the shift in the money demand function is associated with a significant, but one-time reduction in the short-run income elasticity of money demand.

While equation (3-9) is estimated only to determine where the impact of the demand shift occurs, it is interesting to note the values of the coefficients of the other variables. The coefficient on the lagged dependent variable remains about the same and does not consistently move toward unity as the sample period is extended. The RTD variable increases in significance rather than becoming insignificant. This result is consistent with the belief that commercial bank

TABLE XXVII

ESTIMATED CHANGES IN SELECTED COEFFICIENTS OF THE MONEY DEMAND EQUATION

Endpoint	Constant	D_1	m_{t-1}	y_t	Z_t	RCP_t	RTD_t	$\bar{R}^2$	D.W.	S.E.E.	RHO
1975:4	-.0933	.1162	.8663	.1135	-.0760	-.0166	-.0256	.9976	1.77	.0038	.46
	(6.89)	(0.52)	(17.51)	(6.73)	(0.58)	(6.30)	(2.50)				(5.06)
1976:4	-.0933	.1587	.8629	.1144	-.1009	-.0165	-.0263	.9970	1.84	.0037	.45
	(7.08)	(1.29)	(18.17)	(6.90)	(1.41)	(6.43)	(2.62)				(4.97)
1977:4	-.0924	.1160	.8698	.1118	-.0759	-.0162	-.0250	.9972	1.85	.0037	.45
	(7.16)	(2.00)	(19.21)	(7.05)	(2.25)	(6.47)	(2.60)				(5.03)
1978:4	-.0919	.1264	.8543	.1152	-.0817	-.0160	-.0280	.9973	1.83	.0037	.48
	(6.68)	(2.18)	(18.56)	(7.06)	(2.42)	(6.42)	(2.86)				(5.68)

Note: Each estimation period begins with 1952:2. Values in parentheses are absolute t-values.

passbook accounts become relatively more liquid in the 1970s, making them closer substitutes for demand deposits (Porter, Mauskopf, Lindsey, and Berner, 1979, p. 14). In addition, S.E.E. does not steadily increase as the sample period is extended and actually declines slightly.

The first equation in Table XII is used to predict money demand in the 1976-1978 period, and both the static and dynamic simulations track money demand rather well. The equation does not consistently overpredict, and the RMSE's are \$1.51 billion (static) and \$3.13 billion (dynamic).

Even though the results presented above are far from conclusive, they provide general support for the hypothesis that a significant, but one-time change occurs in the relationship between real money balances and real income in the mid-1970s. Whether this shift is due to a change in the σ^2/y ratio (which is in turn doe to the intensive use of cash management services) cannot be determined. The instability could be due to a change in the relationship between income and total transactions, requiring a measure of transactions other than income. Thus far, efforts along this are not able to explain the shortfall in money demand (Goldfeld, 1976; Lieberman, 1979; Kimball, 1980).

Kimball

In his study, Kimball (1980) emphasizes the role of the Federal Reserve's wire transfer network (Fedwire) in the cash management process. In this system, wire transfers are used to consolidate dollar balances as well as to transfer excess dollar balances into interest earning assets. Although there are private wire transfer services, data availability forces Kimball to focus only on those transfers taking place through Fedwire.

Kimball's reasoning for emphasizing the volume of wire transfers is the growing popularity of cash management services requires the ability to transfer funds on an immediately available basis, and the usual way of doing this is through wire transfer. While data on the utilization of money management services are not available, Kimball reasons that the volume of wire transfers acts as a proxy for the utilization of these services and that the increased intensity of cash management efforts is approximated by the increase in the number of wire transfers.

Kimball tests the informational content contined in the volume of wire transfers through Fedwire by estimating and simulating two money demand models. The first equation is a standard money demand equation, while the second adds a variable representing the number of wire transfers through Fedwire. The equations are estimated using annual data, and the estimation results are given as:

$$\ln m_t = \underset{(22.59)}{9.7011} + \underset{(5.98)}{.1728} (\ln(\text{DEBITS/P}) - \underset{(1.76)}{.0258} \ln RTB_t - \underset{(2.24)}{.0651} \ln RCB_t \tag{3-10}$$

$\bar{R}^2 = .7060$ S.E.E. $= .0180$ D.W. $= 1.56$

Sample period = 1949-1974

and

$$\ln m_t = \underset{(4.18)}{4.8015} + \underset{(6.48)}{.5065} \ln (\text{DEBITS/P}) - \underset{(1.43)}{.0185} \ln RTB_t - \underset{(2.28)}{.0383} \ln RCB_t - \underset{(4.27)}{.2925} \ln \text{NOWT} \tag{3-11}$$

$\bar{R}^2 = .9220$ S.E.E. = .0150 D.W. = 1.82

Sample period = 1949-1974

where $m_t = M_t/P_t$ = the demand for real balances,

M_t = the nominal demand for money,

P_t = the GNP deflator

$DEBITS_t$ = the dollar value of debits to demand deposits,

RTB_t = the three-month Treasury bill rate,

RCB_t = the commercial bank passbook rate, and

$NOWT_t$ = the number of wire transfers.

Equation (3-10) is a standard money demand function with a debits to demand deposits variable, rather than real income, serving as the transactions variable. Equation (3-11) includes the number of wire transfers variable in order to reflect the development of cash management innovations over time. In each equation all variables obtain the anticipated signs and, with one exception, are all statistically significant at the .05 level. The exception is the Treasury bill rate, and it is puzzling that this variable is not significant. The coefficient estimates in (3-11) change significantly when the NOWT variable is added. The coefficient on the debits variable increases by almost threefold, while the coefficient on the passbook rate falls by about 40 percent. The standard error of the estimate is slightly lower for equation (3-11), and while a direct comparison of the adjusted R^2s is not appropriate (Granger and Newbold, 1974), it is noted that $\bar{R}^2$ increases substantially when NOWT is added to equation (3-11).

The summary statistics for within-sample and out-of-sample simulations of both equations are found in Table XXVIII. These statistics reveal that there is little difference between the equations for the sample period 1949-1974, as well as for the subperiod 1970-1974. With respect to forecasting ability, equation (3-11) is only slightly better for both periods but is vastly superior for the static and dynamic forecasts that cover 1975-1978. Still, equation (3-11) overpredicts in this period as seen in the mean error of -\$3.0 billion, but the dynamic errors are reduced significantly when compared with those from equation (3-10).

TABLE XXVIII

SIMULATION RESULTS FROM KIMBALL'S MONEY DEMAND EQUATIONS
(BILLIONS OF DOLLARS)

	Equation (3-10)	Equation (3-11)
Mean Error:		
1949-1974	0.6	0.0
1970-1974	-0.1	-0.7
1975-1978 (Static forecast)	-21.3	-2.2
1975-1978 (Dynamic forecast)	-38.2	-3.0
Mean Absolute Error:		
1949-1974	3.0	2.1
1970-1974	5.2	4.0
1975-1978 (Static forecast)	21.3	3.4
1975-1978 (Dynamic forecast)	38.2	3.8
Root Mean Squared Error:		
1949-1974	4.1	2.5
1970-1974	6.6	4.2
1975-1978 (Static forecast)	21.5	4.6
1975-1978 (Dynamic forecast)	38.6	5.2

Source: Kimball (1980), p. 17.

While it appears that Kimball offers new evidence concerning the money demand problem there are reasons for being concerned about his results. One major area of concern is the model suffers from a data problem. Since the NOWT variable stands as a proxy for cash management efforts, this model assumes any increase in NOWT is associated with an increase in the use of money management services. This is not necessarily so since Kimball's NOWT variable includes all wire transfers through Fedwire--interbank, private, and governmental. Therefore, the NOWT variable overstates those transfer connected with cash management efforts. This overstatement is perhaps reduced, since transfers carried by private networks are excluded from NOWT. As an additional matter, it is curious that the Treasury bill rate is not significant in equation (3-11), but that the passbook savings rate remains significant. In the Goldfeld (1976) equation, it is the latter rate that becomes significant over time, while the commercial paper rate on the Treasury bill rate remains significant.

Additional analysis of Kimball's (1980) model is made difficult due to the data limitations surrounding NOWT. Nevertheless, it is clear from the simulation results (Table XXVIII) that the NOWT variable is the crucial feature in Kimball's equation. This is true since both equations predict relatively well in the pre-1975 simulations. It is in the post-1974 simulation that equation (3-11) (with NOWT) continues to track actual money balances relatively well.

By including the NOWT variable in the equation, Kimball assumes that a continuous, downward drift occurs in the money demand function between 1975 and 1978. The reason for this is the NOWT variable takes on different and increasing values between 1975 and 1978 (Kimball, 1980).

The evidence of a continuous, downward drift, however, is inconsistent with the evidence from the quarterly model. This evidence does not imply that a continuous shift takes place in the money demand function. The lack of a continuous drift is suggested in the pattern of the static errors from the quarterly model (Table XIV) and is supported by the dummy variable model of equation (3-9) (Table XXVII).

The dummy variable model of equation (3-9) is applied to the Goldfeld (1976) equation that uses annual data in order to determine if the evidence of a one-time shift is due to the use of disaggregated (quarterly) data. The Goldfeld model using annual data but without the dummy variables is estimated first. This equation is:

$$\ln m_t = b_0 + b_1 \ln y_t + b_2 \ln RCP_t + b_3 \ln RTD_t \qquad (3\text{-}12)$$

All variables are as previously defined. The lagged dependent variable is omitted under the assumption that the adjustment to equilibrium in money holdings is completed within one year.

The ordinary least squares estimation results for equation (3-12) appear in Table XXIX. As is the case for the quarterly model, the annual model displays evidence of a possible misspecification once the post-1974 observations are added to the sample period. This is especially apparent in the standard error of the estimate and in the Durbin-Watson statistic. Contrary to the results from the quarterly model, the savings rate (RTD) in the annual model remains significant over time, while the commercial paper rate (RCP) becomes insignificant. These results are similar to those that Kimball obtains. As in the quarterly model, the income elasticity of money demand declines over time and is actually statistically insignificant by 1977.

TABLE XXIX

ESTIMATES OF EQUATION (3-12) FOR SELECTED YEARS

Endpoint	Constant	y_t	RCP_t	RTD_t	$\bar{R}^2$	S.E.E.	D.W.
1973	-.1211 (3.14)	.3590 (10.72)	-.0189 (1.89)	-.2047 (23.75)	.9829	.0090	1.48
1974	-.1141 (2.76)	.3501 (9.90)	-.0249 (2.41)	-.2015 (22.06)	.9799	.0097	1.65
1975	-.0465 (.63)	.3012 (4.66)	-.0145 (.77)	-.2017 (12.01)	.9878	.0178	0.90
1976	.0804 (.90)	.1886 (2.43)	.0136 (.59)	-.1996 (8.98)	.8993	.0235	0.50
1977	.1762 (2.00)	.1045 (1.36)	.0313 (1.29)	-.1939 (7.94)	.8827	.0260	0.45
1978	.2480 (2.78)	.0477 (.61)	.0314 (1.19)	-.1814 (7.02)	.8674	.0282	0.40

Note: The estimation period for each equation begins in 1952. Each equation is estimated using ordinary least squares.

The dummy variable model of equation (3-9) is applied to equation (3-12) in order to determine if a one-time shift occurs in the model using annual data. This model is:

$$\ln m_t = b_0 + b_1 D_1 + b_2 \ln y_t + b_3 \ln Z_t + b_4 \ln RCP_t + b_5 \ln RTD_t \tag{3-13}$$

where $Z_t = D_1 \ln (y_t)$, and

$D_1 = 1$ for observations after 1974; otherwise, $D_1 = 0$.

If there is a one-time shift in equation (3-12), then the dummy variable model will not break down as the sample period is extended beyond 1974. Since the equation uses annual data, only four observations at most are available for the dummy variable portion of the model. Therefore, equation (3-13) is estimated for the 1952-1978 sample period only. The OLS estimates are:

$$\ln m_t = \underset{(2.75)}{-.1092} + \underset{(2.73)}{.4927}\, D_1 + \underset{(10.22)}{.3521} \ln y_t - \underset{(3.26)}{.3293} \ln Z_t - \underset{(2.36)}{.0277} \ln RCP_t - \underset{(22.86)}{.2020} \ln RTD_t \tag{3-14}$$

$\bar{R}^2 = .9867$ S.E.E. = .0094 D.W. = 1.86

Sample period = 1952-1978

Generally speaking, the results are a repeat of those obtained from estimating the quarterly dummy variable model. The estimates appear to confirm that a one-time shift occurs in the annual model and that most of this shift is captured by the dummy variables. As in the quarterly model, the dummy intercept implies a net increase in the constant term. Again, in terms of the cash management explanation, it is unclear as to why this occurs. The coefficient on the dummy income variable is of the anticipated sign and implies a significant, but one-time reduction in the income elasticity of money demand. In addition, the RCP variable is always significant, the Durbin-Watson statistic gives no indication of autocorrelation in the residuals, and the standard error of the estimate is only slightly larger than that associated with the first equation in Table XXIX.

Kimball's results imply that a continuous shift takes place in the money demand function between 1975 and 1978. The evidence from the quarterly and annual dummy variable models indicate that a one-time shift takes place. The difference in the two sets of results may be due to the inadequacies associated with the NOWT variable. Resolving this issue, therefore, may require more accurate data on wire transfers that are strictly related to the cash management process.

An Analysis of Expected Inflation as the Source of the Money Demand Problem

The role of expected inflation as the source of the money demand problem receives little attention in the literature. This is somewhat surprising since inflation in the U.S. economy becomes prominent in the mid-to-late 1960s and reaches a post-World War II high in 1974:4. This point coincides with the beginning of the money demand problem.

At the theoretical level, an expected inflation variable is not included among the explanatory variables in a transactions demand model since money is not considered to be a substitute for physical goods. It is also assumed that nominal interest rates rise to reflect inflationary expectations, thus eliminating the need for the separate influence of the inflationary expectations variable. Even in the most well-developed financial markets, however, interest rates may not rise to reflect inflationary expectations because of, say, interest rate controls. In such a case, money holders may elect to purchase physical goods rather than holding idle money balances. The switch into physical goods may be especially significant when the expected inflation rate exceeds the nominal return on financial assets.[13]

In his examination of the money demand problem, Goldfeld (1976) estimates two money demand equations that include expected inflation variables. In each equation, the expected inflation variable is formed as a distributed lag of past inflation rates. These equations are:

$$\ln m_t = b_0 + b_1 \ln m_{t-1} + b_2 \ln y_t + b_3 \ln RCP_t + b_4 \ln RTD_t + \sum_{j=1}^{n_1} b_{5j} \pi_{t-j} \tag{3-14}$$

and

$$\ln m_t = b_0 + \sum_{j=0}^{n_1} b_{1j} \ln y_{t-j} + \sum_{j=0}^{n_2} b_{2j} \ln RCP_{t-j} + \sum_{j=0}^{n_3} b_{3j} \ln RTD_{t-j} + \sum_{j=1}^{n_4} b_{4j} \pi_{t-j} \tag{3-15}$$

where π_t = the actual rate of inflation as measured by the GNP deflator.

Goldfeld does not report his results, but he notes the expected inflation variable is significant in both equations. Post-sample simulations of equations (3-14) and (3-15) reveal that money demand is still overpredicted, which leads Goldfeld to conclude the money demand

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[13] This argument is briefly summarized in Dornbusch and Fischer (1981).

problem is not explained by the relatively high rates of inflation that occur in the mid-1970s.

While Goldfeld's conclusions may be correct, his analysis is limited in several respects. Since Goldfeld uses a distributed lag model to form the expected inflation variable, he assumes money holders only use current and past inflation rates as their information set in forming their expectations of inflation. If one believes expectation formation should be consistent with the notion of rationality as Muth (1961) proposes, then money holders may draw upon additional information in forming their inflation forecasts.

Another limitation of Goldfeld's (1976) method is he uses all observations in his data set (1952-1973) to generate a forecast of inflation at time t+j. In other words, by Goldfeld's approach, the money holder uses the information of time t, t+1, ..., t+j-1, t+j, t+j+1, ..., T, to form a forecast of inflation at time t+j. Of course, the information at time t+j, t+j+1, ..., T is not available to an agent at time t+j.

A final limitation of Goldfeld's method is he assumes the expected inflation variable is important in the money demand function over the entire 1952-1973 period, and these expectations are generated by the same model over the entire period. It seems more plausible to believe if expected inflation is the cause of the money demand problem, then this variable should enter the equation with a threshold effect, either in the late 1960s or mid-1970s. It also seems plausible to believe forecasts of inflation in the late 1960s and early 1970s are generated by a model different from that of the 1950s and early 1960s.

With these limitations in mind, the impact of expected inflation on money demand in the post-1973 period is reconsidered in this section. In estimating the money demand equations that include an expected inflation variable, it is assumed that inflation enters the equation with a threshold effect. Specifically, the inflation variable enters the function in 1974:1. This date is selected because inflation is assumed to have become significant in the U.S. economy only as early as the mid-19760s, and the method that is used here to generate the inflation forecasts "uses up" the observations prior to 1974. Hence, the first available forecast of inflation is for 1974:1. Also, the money demand problem appears rather abruptly in late 1974 or early 1975, which may indicate the expected inflation variable becomes important only as early as the mid-1970s.

Regarding the generation of inflation forecasts, a method due to Pearce (1979) is used to obtain forecasts of inflation. Specifically, observations through time t+j (1973:4) are used to estimate a model of inflation. This model is used to forecast inflation for time t+j+1 (1974:1). The observations through time t+j+1 are then used to estimate another model of inflation, and this model is used to form a forecast of inflation for time t+j+2 (1974:2). This process continues until an inflation forecast is obtained for time t+j+k (1978:4). The expected inflation series that results from this procedure is added to the Goldfeld (1976) equation, and the equation is re-estimated in order to determine the impact of (or the lack thereof) expected inflation on money demand between 1974 and 1978.

Two models of inflation are estimated. These models are:

$$\pi_t = \pi_{t-1} + a_t - \theta_1 a_{t-1} \tag{3-16}$$

and

$$\pi_t = \sum_{j=1}^{n_1} b_j \pi_{t-j} + \sum_{j=1}^{n_2} c_j \dot{M}_{t-j} + \sum_{j=1}^{n_3} d_j S_{t-j} + D_1 + D_2 \qquad (3\text{-}17)$$

where π_t = the current rate of inflation (expressed at an annual rate) as measured by the implicit GNP deflator,

a_t = a white noise process ($a \sim N(0,\sigma_{aa})$),

$\dot{M}_t$ = the growth rate of the nominal supply of money (measured at an annual rate),

S_t = the high employment federal budget surplus,

D_1 = a price control variable, where D_1 = 1 for 1973:4-1974:1; otherwise D_1 = 0, and

D_2 = a price decontrol variable, where D_2 = 1 for 1974:2-1974:4; other wise D_2 = 0.

As a time series model, equation (3-16) is an IMA(1,1) model. Similar models for the Consumer Price Index and the Wholesale Price Index series are obtained by Feige and Pearce (1976). Equation (3-16) implies the only information set that is used in forming expectations of inflation is that contained in the past history of inflation itself. This forecast of inflation is the one-step ahead forecast generated by (3-16) and is given as:

$$\hat{\pi}_t(1) = \pi_t - \hat{\theta}_1 \hat{a}_t \qquad (3\text{-}18)$$

According to (3-18), inflationary expectations are generated by the adaptive expectations model of Cagan (1956). This is seen by rewriting the equation as:

$$\begin{aligned} \hat{\pi}_t(1) &= \pi_t - \hat{\theta}_1(\pi_t - \hat{\pi}_{t-1}(1)) \\ &= \pi_t - \hat{\theta}_1 \pi_t + \hat{\theta}_1 \hat{\pi}_{t-1}(1) \end{aligned}$$

$$= \pi_t - (1 - \delta)\pi_t + (1 - \delta)\hat{\pi}_{t-1}(1)$$
$$= \hat{\pi}_{t-1}(1) + \delta(\pi_t - \hat{\pi}_{t-1}(1)).$$

The last equality is the same as the adaptive expectations forecasting formula.

Equation (3-17) assumes that a wider information set is used in forming expectations of inflation. Agents are assumed to incorporate past information on inflation, a monetary variable and a fiscal variable into their expectations generating model. In addition, two dummy variables are included to account for the imposition of wage and price controls in 1971:3 and their subsequent removal in 1974:2.

Using the method described above, the expected inflation series are generated by equations (3-16) and (3-17). In estimating the inflation equations, it is believed that the relevant sample period should begin with 1966. While selection of the year 1966 may seem quite arbitrary, Table XXX shows that 1966 provides a boundary between a period of mild inflation and a period of sharply higher inflation. A similar conclusion is reached by Mulleneux (1980) in his study of the formation of inflationary expectations.

It is not appropriate to identify and to estimate (3-16) with a sample beginning with 1966 since (3-16) is a time series model, and these models require relatively large samples in the identification and estimation processes. Consequently, the sample period for (3-16) begins with 1961. This allows the inflation models to be estimated with at least 47 observations. Expanding the sample in this manner is not considered critical for the ARIMA models since inflation begins its upward movement in 1961.

TABLE XXX

U.S. INFLATION, 1952-1978

Date	Inflation Rate[a]
1952	1.21
1953	1.54
1954	1.35
1955	2.15
1956	3.07
1957	3.28
1958	1.68
1959	2.10
1960	1.76
1961	0.87
1962	1.86
1963	1.41
1964	1.52
1965	2.18
1966	3.31
1967	2.82
1968	4.46
1969	4.84
1970	5.28
1971	4.91
1972	4.08
1973	5.64
1974	9.20
1975	9.22
1976	4.98
1977	5.81
1978	7.02

[a]Calculated as the year-to-year rate of change in the GNP deflator.

The maximum likelihood estimates of the IMA(1,1) model are presented in Table XXXI. The one-step ahead forecasts along with the forecast errors are also presented in the table. The model appears to be identified correctly in view of the relatively low Box-Pierce χ^2 statistics and in view of the significant t-values.

The estimates of θ_1 tend to decline as the sample period is extended. From an adaptive expectations point of view, this is to be expected since a decline in θ_1 indicates that agents place more weight on more recent inflation rates. This may be shown by noting equation (3-16) can be expressed as:

$$(1-B)\pi_t = a_t(1-\theta B) \tag{3-16)'}$$

where B = a backshift operator such that $B\pi_t = \pi_{t-1}$, $B^2\pi_t = \pi_{t-2}$, etc. Equation (3-16)' is rearranged as:

$$\frac{(1 - B)}{(1 - \theta_1 B)} \pi_t = a_t$$

or

$$(1 - \gamma_1 B - \gamma_2 B^2 - \gamma_3 B^3 - \ldots)\pi_t = a_t.$$

The last equation shows that the IMA(1,1) model of inflation can be expressed as an infinite distributed lag model. The γ_j weights decline geometrically and are calculated as:

$$\begin{aligned}
\gamma_1 &= 1 - \theta && = \delta \\
\gamma_2 &= \theta_1\gamma_1 && = \delta(1 - \delta) \\
\gamma_3 &= \theta_1\gamma_2 && = \delta(1 - \delta)^2 \\
&\vdots && \vdots \\
\gamma_j &= \theta_1\gamma_{j-1} && = \delta(1 - \delta)^{j-1}
\end{aligned}$$

TABLE XXXI

IMA(1,1) MODELS OF INFLATION, 1974-1978

Endpoint	$\hat{\theta}_1$	S.E.E.	χ^{2a}	One-Step Ahead Forecast	Forecast Error
1973:4	.5774 (4.56)	1.2529	13.82	7.79	0.31
1974:1	.5917 (5.05)	1.2357	13.88	7.96	2.89
1974:2	.5190 (4.09)	1.2833	15.04	8.82	2.15
1974:3	.4886 (3.94)	1.2809	17.29	10.44	1.43
1974:4	.4639 (4.23)	1.2805	15.52	11.34	-1.23
1975:1	.4934 (3.76)	1.2880	13.09	10.76	-5.03
1975:2	.4896 (3.76)	1.4445	12.34	8.21	-1.16
1975:3	.4295 (3.44)	1.4406	13.68	7.48	-1.44
1975:4	.3883 (3.13)	1.4418	14.37	6.59	-3.04
1976:1	.3364 (2.61)	1.4844	15.88	4.55	-0.04
1976:2	.3337 (2.73)	1.4722	16.18	4.55	0.12
1976:3	.3340 (2.77)	1.4601	16.39	4.66	1.22
1976:4	.3358 (2.80)	1.4558	17.45	5.51	0.31
1977:1	.3347 (2.82)	1.4444	17.84	5.74	1.68
1977:2	.3274 (2.75)	1.4468	19.46	6.92	-2.24
1977:3	.3558 (3.05)	1.4624	14.43	5.48	0.73
1977:4	.3610 (3.15)	1.4536	14.97	5.99	0.12
1978:1	.3614 (3.18)	1.4427	15.28	6.10	4.03
1978:2	.3551 (2.99)	1.5097	14.93	8.77	-1.85
1978:3	.4001 (3.63)	1.5133	15.24	7.62	0.71

[a]χ^2 is the Box-Pierce χ^2 statistic and is based on 20 d.f. The sample period for each equation begins with 1961:2.

A reduction in θ_1 implies an increase in δ, and since the weights decline geometrically, an increase in δ places more weight on more recent observations of inflation.

The γ_j weights for each of the IMA(1,1) models from Table XXXI are presented in Table XXXII. As the sample period is extended, the γ_1 weight increases in value while the γ_2 weight shows little change. The remaining weights in Table XXXII decline in value.

Returning to Table XXXI, one sees the IMA(1,1) model of inflation achieves mixed results in predicting inflation. The model does not accurately predict the sharp run-up in inflation that occurs in 1974 and tends to overpredict inflation in 1975 as inflation moderates. This is expected since the IMA(1,1) model places more weight on recent observations of inflation.

Equation (3-17) is estimated next. Because the dummy price control and the high employment federal budget surplus variables are not significant, the equations are re-estimated with these variables omitted. The insignificance of the fiscal variable is consistent with the results in Mulleneux (1980). The insignificance of the dummy price control variable may be due to the fact that inflation in 1971 is declining even as controls are put into place. If money holders look to past money growth rates in forming their expectations of inflation (and the results given below support this), then the reduction in money growth prior to the control period may be more influential in shaping expectations of a lower inflation rate than the controls themselves.

The results from estimating (3-17) are found in Table XXXIII. The one-step ahead forecasts and forecast errors are also included in

TABLE XXXII

IMPLIED γ_j WEIGHTS FROM IMA(1,1) MODELS OF INFLATION, 1974-1978

Endpoint	γ_1	γ_2	γ_3	γ_4	γ_5	γ_6
1973:4	.4226	.2440	.1409	.0814	.0470	.0271
1974:1	.4083	.2416	.1429	.0846	.0500	.0296
:2	.4840	.2497	.1289	.0665	.0343	.0177
:3	.5114	.2499	.1221	.0597	.0291	.0142
:4	.5361	.2487	.1154	.0535	.0248	.0115
1975:1	.5066	.2500	.1233	.0609	.0300	.0148
:2	.5104	.2499	.1224	.0599	.0293	.0144
:3	.5705	.2450	.1052	.0452	.0194	.0083
:4	.6117	.2375	.0922	.0358	.0139	.0054
1976:1	.6636	.2232	.0751	.0253	.0085	.0029
:2	.6663	.2223	.0742	.0248	.0083	.0028
:3	.6660	.2224	.0742	.0248	.0083	.0028
:4	.6642	.2230	.0749	.0252	.0084	.0028
1977:1	.6653	.2227	.0745	.0249	.0083	.0028
:2	.6726	.2202	.0721	.0236	.0077	.0025
:3	.6442	.2292	.0816	.0290	.0103	.0037
:4	.6390	.2326	.0840	.0303	.0109	.0039
1978:1	.6386	.2308	.0834	.0301	.0109	.0039
:2	.6449	.2290	.0813	.0289	.0103	.0036
:3	.5999	.2400	.0960	.0384	.0154	.0062

TABLE XXXIII

ESTIMATES OF EQUATION (3-17) FOR SELECTED YEARS

Endpoint	π_{t-1}	D_2	Σc_j	$\Sigma c_j/1-b_0$	$\bar{R}^2$	S.E.E.	D.W.	One-Step Ahead Forecast	Forecast Error
1973:4	.3762	a	.5983	.9591	.4240	1.21	1.82	8.20	-0.10
	(1.90)		(3.33)						
1974:1	.3762	a	.5983	.9591	.6090	1.21	1.84	7.82	3.03
	(1.90)		(3.33)						
1974:2	.3418	3.38	.6276	.9535	.7026	1.19	1.77	11.89	-0.92
	(1.81)	(3.07)	(3.50)						
1974:3	.3535	3.49	.6175	.9551	.7750	1.17	1.82	11.57	0.30
	(1.94)	(3.41)	(3.66)						
1974:4	.4884	2.87	.5073	.9912	.7949	1.17	2.02	11.88	-1.77
	(3.50)	(3.28)	(3.63)						
1975:1	.3940	3.34	.5812	.9591	.7590	1.22	1.97	8.31	-2.58
	(2.94)	(3.83)	(4.19)						
1975:2	.3902	3.25	.5956	.9767	.7434	1.24	2.13	5.77	1.28
	(2.88)	(2.88)	(4.29)						
1975:3	.3966	3.22	.5909	.9793	.7715	1.22	2.18	6.07	-0.03
	(3.05)	(3.78)	(4.21)						
1975:4	.3790	3.35	.5987	.9721	.7355	1.24	2.09	5.36	-1.81
	(2.87)	(3.88)	(4.29)						
1976:1	.3752	3.35	.6037	.9662	.7661	1.22	2.18	4.31	0.20
	(2.93)	(3.95)	(4.64)						
1976:2	.3749	3.35	.6043	.9667	.7439	1.20	2.18	4.64	0.03

TABLE XXXIII (Continued)

Endpoint	π_{t-1}	D_2	Σc_j	$\Sigma c_j/1-b_0$	$\bar{R}^2$	S.E.E.	D.W.	One-Step Ahead Forecast	Forecast Error
1976:3	.3825 (3.03)	3.29 (3.93)	.6033 (4.62)	.9770	.7572	1.20	2.13	4.67	1.21
1976:4	.3951 (3.20)	3.24 (3.93)	.5942 (4.54)	.9663	.7295	1.19	2.14	4.91	0.91
1977:1	.4237 (3.35)	3.67 (3.67)	.5756 (4.46)	.9988	.7051	1.23	2.03	5.09	2.33
1977:2	.3851 (3.14)	3.84 (3.84)	.6079 (4.69)	.9886	.6967	1.24	2.13	6.04	-1.36
1977:3	.3771 (3.12)	3.24 (3.87)	.6205 (4.77)	.9961	.6931	1.23	2.18	4.96	1.25
1977:4	.3775 (3.17)	3.93 (3.93)	.6205 (4.77)	1.0040	.6939	1.21	2.19	5.97	0.14
1978:1	.4056 (3.02)	3.11 (3.34)	.6094 (4.36)	1.0252	.6094	1.37	1.97	6.01	4.12
1978:2	.3636 (2.90)	3.26 (3.56)	.6464 (4.64)	1.0157	.6464	1.36	2.23	7.94	-1.02
1978:3	.3638 (2.91)	3.21 (3.53)	.6538 (4.64)	1.0264	.6263	1.36	2.27	6.86	1.47

[a]Not relevant until 1974:2 (see text, p. 89).

Note: Each equation is estimated using ordinary least squares. The sample period for each equation begins with 1966:1.

the table. The distributed lag on the inflation variable is assumed to follow a second degree polynomial, but only the b_1 coefficient is found to be significant. The distributed lag on the money growth variable is also assumed to follow a second degree polynomial where the c_0 coefficient is constrained to be zero. This constraint is imposed since, in forming a forecast of inflation at time t+j, one does not have knowledge of the growth rate of the money supply at time t+j. The length of the lag is determined empirically and an 11 quarter lag is found to be appropriate. This result is consistent with the 12 quarter lag recently reported by Carlson (1980) from a monetary model of the inflation process. In all cases the sum of the lag coefficients are significantly different from zero. Also, the implied long-run elasticity of the price level with respect to money ($\Sigma c_j/1 - b_0$) is always close to unity, which indicates that long-run inflation is approximately equal to long-term money growth. Finally, the dummy price decontrol variable is always significant and of the anticipated sign.

In terms of the one-step-ahead forecasts, equation (3-17) performs only slightly better than equation (3-16). The RMSEs are 2.06 (equation 3-16) and 1.68 (equation 3-17). Like equation (3-16), equation (3-17) experiences some difficulty in forecasting inflation during the 1974-1975 period.

Money demand equations are estimated that include each of the expected inflation series. The inflation variable is assumed to enter the money demand function with a threshold effect and is not included in the function until 1974:1, at which point it is entered with a dummy variable.

The money demand equations with the added inflation variable are estimated by three methods. In the first method, the expected inflation series are simply added to the Goldfeld (1976) equation. Since expectations of inflation are correlated with interest rates and the lagged money supply, a serious multicollinearity problem is associated with this first method. Consequently, in the second method, all variables in the equation are first-differenced prior to estimation. While there may be substantial correlation between the variables in level form, there is no reason to suspect a high degree of correlation between the first-differences of the same variables. The first-difference equations are:[14]

$$\begin{aligned}\Delta \ln m_t = {} & b_1 \, \Delta \ln m_{t-1} + b_2 \, \Delta \ln y_t + b_3 \, \Delta \ln RCP_t + \\ & b_4 \, \Delta \ln RTD_t + b_5 \, \Delta \ln \pi_t^*\end{aligned} \tag{3-19}$$

where π_t^* = the expected rate of inflation from either equation (3-16) or (3-17).

In the third method a suggestion due to Modigliani (Dornbusch and Fischer, 1981, pp. 244-245) is used to incorporate the expected inflation rate into the money demand function. Working within a portfolio framework, Modigliani argues that in periods when the expected rate of inflation exceeds the nominal rate of interest, individuals begin to purchase goods rather than holding money. In this case the expected rate of inflation exerts a separate influence on money demand. Modigliani offers a rule for determining whether to include the nominal rate of interest or the expected inflation rate in the money demand function. If the nominal rate of interest

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[14]Since π_t^* is always positive, it is appropriate to enter this variable in log form.

exceeds the expected inflation rate, then the nominal interest rate is not necessary. If the expected inflation rate exceeds the nominal interest rate, then the expected rate of inflation is the true cost of holding money.

For simplicity, a money demand equation that only includes one interest rate--the commercial paper rate--is estimated. This equation is:

$$\ln m_t = b_0 + b_1 \ln m_{t-1} + b_2 \ln y_t + b_3 \ln X_t + b_4 \ln Z_t \qquad (3\text{-}20)$$

where $X_t = D_1 \, RCP_t$,

$Z_t = D_2 \, \pi^*_t$,

D_1 = a dummy variable such that $D_1 = 1$ when $RCP_t > \pi^*_t$; otherwise, $D_1 = 0$, and

D_2 = a dummy variable such that $D_2 = 1$ when $RCP_t < \pi^*_t$; otherwise, $D_2 = 0$.

Since the expected inflation variable and the interest rate variable do not enter the equation concurrently, the problem of multicollinearity is avoided. Hence, the equation is estimated in log-level form.

Before presenting the estimation results, it is interesting to note that in testing the hypothesis that the money demand problem is explained in terms of inflationary expectations, one is also indirectly testing the validity of the one-time shift hypothesis of equation (3-9). The results from estimating (3-9) support the argument that a one-time shift occurs in the money demand function in 1975. The one-time shift argument is also suggested by the static simulation results from the Goldfeld (1976) equation. By including the expected inflation variable in the equation, however, one is asserting that a continuous shift takes place between 1974 and 1978. A finding of insignificance for the inflation variable would be consistent with the evidence from equation (3-9).

The results from estimating the Goldfeld (1976) equation with an expected inflation variable are presented in Tables XXXIV and XXXV. As is seen in both tables, the expected inflation variables always obtain the expected negative sign, but they are never statistically significant. Even more revealing is the fact that the addition of the inflation variables to the Goldfeld equation does not prevent the deterioration of the equation in terms of the other variables. By 1975, the lagged dependent variable is not statistically different from one, and the RTD variable is no longer significant.

The results from estimating equation (3-19) for each of the two inflation variables are contained in Tables XXXVI and XXXVII. Once again, the inflation variables are of the anticipated sign but add nothing toward explaining money demand between 1974 and 1978. While the equation does not deteriorate in terms of the other coefficients as the sample period is extended, these satisfactory results are due to the addition of the inflation variable. Further consideration of the model in first-difference form is postponed until Chapter IV.

The coefficient estimates from equation (3-20) are presented in Tables XXXVIII and XXXIX. Even though the inflation variable is always significant, the equation deteriorates badly in terms of the other coefficient estimates as soon as the 1975 observations are added to the sample. While Modigliani's method for determining the relevant opportunity costs of holding money receives some statistical support, this method does not explain the breakdown in the money demand relationship.

TABLE XXXIV

ESTIMATES OF THE GOLDFELD MONEY DEMAND EQUATION WHERE THE INCLUDED EXPECTED INFLATION VARIABLE IS GENERATED BY EQUATION (3-16)

Endpoint	Constant	m_{t-1}	y_t	RCP_t	RTD_t	π_t^*	$\bar{R}^2$	S.E.E.	D.W.	RHO
1974:4	-.0941 (6.99)	.8573 (16.96)	.1159 (6.63)	-.0167 (6.45)	-.0266 (2.49)	-.0007 (0.50)	.9964	.0036	1.81	.47 (5.06)
1975:4	-.0887 (6.70)	.9471 (21.00)	.0878 (5.50)	-.0142 (5.41)	-.0095 (0.97)	-.0023 (1.61)	.9961	.0040	1.78	.41 (4.28)
1976:4	-.0822 (6.19)	.9929 (25.91)	.0706 (5.27)	-.0132 (5.01)	.0002 (0.02)	-.0019 (1.34)	.9963	.0040	1.87	.42 (4.52)
1977:4	-.0805 (6.44)	1.0060 (29.52)	.0658 (5.71)	-.0130 (5.11)	.0030 (0.40)	-.0018 (1.28)	.9966	.0040	1.88	.40 (4.42)
1978:4	-.0808 (6.61)	1.0135 (32.71)	.0642 (6.05)	-.0135 (5.51)	.0049 (0.73)	-.0017 (1.24)	.9968	.0040	1.86	.39 (4.33)

Note: The estimation period for each equation begins with 1952:2.

TABLE XXXV

ESTIMATES OF THE GOLDFELD MONEY DEMAND EQUATION WHERE THE INCLUDED EXPECTED INFLATION VARIABLE IS GENERATED BY EQUATION (3-17)

Endpoint	Constant	m_{t-1}	y_t	RCP_t	RTD_t	π^*_t	$\bar{R}^2$	S.E.E.	D.W.	RHO
1974:4	-.0951	.8570	.1173	-.0167	-.0275	-.0008	.9966	.0036	1.81	.49
	(6.86)	(16.80)	(6.82)	(6.31)	(2.54)	(0.55)				(5.34)
1975:4	-.0886	.9573	.0856	-.0142	-.0081	-.0019	.9962	.0040	1.77	.43
	(6.47)	(21.82)	(5.45)	(5.24)	(0.85)	(1.32)				(4.62)
1976:4	-.0828	.9963	.0706	-.0132	.0001	-.0017	.9964	.0041	1.87	.44
	(6.07)	(26.42)	(5.31)	(4.89)	(0.15)	(1.21)				(4.78)
1977:4	-.0812	1.0085	.0060	-.0129	.0028	-.0017	.9967	.0040	1.88	.42
	(6.33)	(29.97)	(5.75)	(4.98)	(0.38)	(1.19)				(1.19)
1978:4	-.0814	1.0165	.0644	-.0135	.0048	-.0015	.9969	.0040	1.86	.41
	(6.49)	(33.08)	(6.05)	(5.39)	(0.72)	(1.13)				(1.13)

Note: The estimation period for each equation begins with 1952:2.

TABLE XXXVI

ESTIMATES OF EQUATION (3-19) WHERE THE INCLUDED EXPECTED INFLATION VARIABLE IS GENERATED BY EQUATION (3-16)

Endpoint	Δm_{t-1}	Δy_t	ΔRCP_t	ΔRTD_t	$\Delta\pi^*_t$	$\bar{R}^2$	S.E.E.	D.W.
1974:4	.7225 (10.08)	.1520 (3.52)	-.0173 (5.09)	-.0364 (2.56)	-.0377 (1.66)	.7115	.0040	2.12
1975:4	.7743 (11.34)	.1594 (3.51)	-.0156 (4.38)	-.0340 (2.26)	-.0085 (0.67)	.6809	.0043	2.03
1976:4	.7691 (11.45)	.1520 (3.52)	-.0152 (4.36)	-.0340 (2.28)	-.0086 (1.02)	.6721	.0043	2.10
1977:4	.7714 (11.66)	.1562 (3.87)	-.0152 (4.43)	-.0340 (2.31)	-.0052 (0.77)	.6747	.0043	2.15
1978:4	.7824 (12.14)	.1546 (3.91)	-.0162 (4.77)	-.0325 (2.22)	-.0030 (0.53)	.6667	.0043	2.13

Note: Each equation is estimated using ordinary least squares. The estimation period for each equation begins with 1952:2.

TABLE XXXVII

ESTIMATES OF EQUATION (3-19) WHERE THE INCLUDED EXPECTED INFLATION VARIABLE IS GENERATED BY EQUATION (3-17)

Endpoint	Δm_{t-1}	Δy_t	ΔRCP_t	ΔRTD_t	$\Delta \pi_t^*$	$\bar{R}^2$	S.E.E.	D.W.
1974:4	.7470 (11.01)	.1498 (3.44)	-.0161 (4.56)	-.0348 (2.46)	-.0164 (1.45)	.7095	.0041	2.08
1975:4	.7804 (11.48)	.1637 (3.66)	-.0153 (4.15)	-.0338 (2.25)	-.0033 (0.43)	.6803	.0043	2.04
1976:4	.7749 (11.51)	.1552 (3.63)	-.0145 (4.05)	-.0340 (2.27)	-.0065 (0.89)	.6711	.0043	2.09
1977:4	.7760 (11.74)	.1553 (3.84)	-.0145 (4.17)	-.0338 (2.30)	-.0058 (0.87)	.6750	.0043	2.12
1978:4	.7847 (12.16)	.1541 (3.89)	-.0158 (4.60)	-.0325 (2.22)	-.0034 (0.56)	.6667	.0043	2.12

Note: The estimation period for each equation begins with 1952:2.

TABLE XXXVIII

ESTIMATES OF EQUATION (3-20) WHERE THE INCLUDED EXPECTED INFLATION VARIABLE IS GENERATED BY EQUATION (3-16)

Endpoint	Constant	m_{t-1}	y_t	X_t	Z_t	$\bar{R}^2$	S.E.E.	D.W.	RHO
1974:4	-.0945	.8337	.1224	-.0717	-.0186	.9965	.0036	1.81	.49
	(7.02)	(16.30)	(7.01)	(6.66)	(6.27)				(5.27)
1975:4	-.0890	.8946	.1021	-.0156	-.0182	.9964	.0038	1.73	.43
	(6.85)	(18.84)	(6.29)	(6.13)	(6.33)				(4.59)
1976:4	-.0788	.9932	.0682	-.0140	-.0142	.9964	.0040	1.85	.47
	(5.64)	(28.73)	(5.54)	(5.27)	(5.35)				(5.24)
1977:4	-.0768	1.0126	.0614	-.0136	-.0134	.9966	.0040	1.87	.44
	(5.92)	(33.82)	(5.94)	(5.38)	(5.32)				(4.96)
1978:4	-.0769	1.0289	.0577	-.0142	-.0134	.9968	.0040	1.85	.42
	(6.14)	(40.54)	(6.33)	(5.83)	(5.51)				(4.76)

Note: The estimation period for each equation begins with 1952:2.

TABLE XXXIX

ESTIMATES OF EQUATION (3-20) WHERE THE INCLUDED EXPECTED INFLATION VARIABLE IS GENERATED BY EQUATION (3-17)

Endpoint	Constant	m_{t-1}	y_t	X_t	Z_t	$\bar{R}^2$	S.E.E.	D.W.	Rho
1974:4	-.0956 (6.89)	.8372 (17.08)	.1228 (7.12)	-.0170 (6.50)	-.0176 (6.67)	.9966	.0036	1.81	.50 (5.55)
1975:4	-.0866 (6.21)	.9684 (25.34)	.0818 (5.70)	-.0151 (5.52)	-.0153 (5.64)	.9963	.0040	1.76	.45 (4.94)
1976:4	-.0800 (5.74)	1.0117 (31.84)	.0649 (5.48)	-.0139 (5.11)	-.0138 (5.20)	.9964	.0041	1.88	.46 (5.15)
1977:4	-.0782 (5.97)	1.0238 (36.49)	.0602 (6.00)	-.0136 (5.25)	-.0135 (5.25)	.9967	.0040	1.89	.44 (5.00)
1978:4	-.0783 (6.16)	1.0327 (41.85)	.0582 (6.45)	-.0141 (5.66)	-.0140 (5.54)	.9969	.0040	1.87	.43 (4.85)

Note: The estimation period for each equation begins with 1952:2.

The methods and evidence of this section lead to the conclusion that the money demand problem is not to be explained by an expected inflation variable. This conclusion is in agreement with that obtained by Goldfeld (1976).

Summary

This chapter analyzes the omitted variable explanation of the money demand problem. This explanation states that the money demand problem is the result of excluding an important explanatory variable from the equation. Researchers who support this explanation present money demand models incorporating what those researchers consider to be the appropriate missing variable. Where empirical results are presented, they are rather impressive in terms of explaining the demand for money in the post-1973 period.

Since each model cannot be correct, this chapter analyzes each model in an effort to narrow the list of those variables that may properly be considered as the omitted variable in the money demand equation. The analysis allows for a common treatment of each model in terms of a common data base and in terms of a common sample period. Where appropriate, the analysis also allows for an extension of a model's results to include more recent observations. The chapter also considers the role of inflationary expectations in explaining the money demand problem.

The analysis of this chapter rejects the models of Hamburger (1977), Friedman (1979), Quick and Paulus (n.d.), and Kimball (1980). In addition, the inflationary expectations variable is not found to be the source of the money demand problem.

On the other hand, the analysis suggests that a one-time shift occurs in the money demand function in the mid-1970s, and that a significant portion of this shift is explained by a one-time reduction in the income elasticity of money demand. While such results are consistent with the implications of the Porter and Mauskopf (n.d.) model, they only indirectly support this explanation since the Porter and Mauskopf model is itself not directly testable.

CHAPTER IV

THE INCORRECT ESTIMATION TECHNIQUE ARGUMENT

Introduction

The definitional explanation and the omitted variable explanation attribute the money demand problem to a misspecification either in the dependent variable or in the explanatory variables. These explanations suggest that stability is returned to the money demand function when the function is correctly specified. There is a third explanation stating that the traditional money demand function is correctly specified but is estimated with an inappropriate estimation technique. The use of an incorrect estimation technique is the source of the money demand problem.

Hafer and Hein (1980) of the Federal Reserve Bank of St. Louis recently produce results showing the money demand function is stable when estimated in log-difference form using the ordinary least-squares technique. Rather than applying the Cochrane-Orcutt technique to the log-level model,

$$\begin{aligned} \ln m_t = b_0 + b_1 \ln m_{t-1} + b_2 \ln y_t + b_3 \ln RCP_t + \\ b_4 \, RTD_t + e_t \qquad (e_t = \rho e_{t-1} + n_t) \end{aligned} \tag{4-1}$$

Hafer and Hein (1980) estimate the log-difference model:[1]

[1]This approach actually represents a reversal of a position taken in an earlier paper (Hafer and Hein, 1979). In the earlier paper,

$$\Delta \ln m_t = b_1\ \Delta \ln m_{t-1} + b_2\ \Delta \ln y_t + b_3\ \Delta \ln RCP_t + b_4\ \Delta \ln RTD_t + n_t \tag{4-2}$$

Assuming $\rho = 1$, then $b_j = a_j$ $(j = 1, 2, 3, 4)$.

According to Hafer and Hein (1980), estimating (4-2) using OLS avoids the econometric problems associated with estimating (4-1) using the Cochrane-Orcutt method. Specifically, since (4-1) includes a lagged dependent variable, the Cochrane-Orcutt technique underestimates the absolute value of ρ (Theil, 1971). This error results in coefficient estimates that are inconsistent and inefficient. If n_t in equation (4-2) is serially independent, then estimation of (4-2) avoids the problems associated with estimating (4-1).[2]

When Hafer and Hein estimate (4-2) for sample periods extending beyond 1973, they obtain coefficient estimates that give every indication of stability in the money demand equation. In addition, their model tracks money demand relatively well in a series of four-quarter post-sample simulations. Hence, Hafer and Hein conclude that the money demand problem is econometric in nature, and the solution becomes one of choosing the correct estimation technique.

Hafer and Hein argue that the equation in level form is stable. However, the money demand equation they use in this particular study violates the assumption of their stability tests. These tests are developed by Brown, Durbin and Evans (1975) and require a constant serial correlation coefficient, nonstochastic explanatory variables and a constant error variance--none of which are met by the earlier Hafer and Hein equation. Subsequent data revisions indicate that the equation in log-level form is not stable.

[2]Granger and Newbold (1974) also advocate first-differencing as a method avoiding the problems of estimating models with nonstationary error series.

This chapter analyzes the Hafer and Hein (1980) explanation in an effort to explain why equation (4-2), unlike equation (4-1), does not break down in the post-1973 period. Hafer and Hein's results are reviewed first. It is then demonstrated that equation (4-2) may be considered to be a special case of the more general transfer function model (Box and Jenkins, 1976). A transfer function model is estimated and simulated and these results are compared to those from the Hafer and Hein model. It is then shown that Hafer and Hein's results are inconclusive and may actually mask a shift that occurs in the money demand relationship.

Hafer and Hein's Estimation Results

Hafer and Hein (1980) estimate two versions of (4-2). In the first version, the real adjustment mechanism is assumed where the lagged dependent variable is ($\ln M_{t-1}/P_{t-1} - \ln M_{t-2}/P_{t-2}$). In the second version, the nominal adjustment mechanism is assumed where the lagged dependent variable is ($\ln M_{t-1}/P_t - \ln M_{t-2}/P_{t-1}$).

Hafer and Hein's results appear in Table XL. With one exception, the coefficients show a remarkable degree of stability as the sample is extended. The income coefficient does not decline over time, and the coefficient on the lagged dependent variable does not steadily increase (approaching one) as is the case for the model in level form. The RTD variable becomes insignificant in the nominal adjustment version after 1973:4. It is unclear why this occurs since the only difference in the models is in the adjustment mechanism. F-tests indicate stability in the coefficients for various subperiods of the total sample for both versions of the model, while the Durbin-Watson and

TABLE XL

THE HAFER AND HEIN MONEY DEMAND EQUATION

Endpoint	Adjustment	Δm_{t-1}	Δy_t	ΔRCP_t	ΔRTD_t	$\bar{R}^2$	S.E.E.	Durbin h	D.W.	Static 4Q RMSE
1973:4	Real	.548	.171	-.013	-.051	.5280	.0047	.30		.0084
		(5.66)	(2.56)	(2.90)	(3.00)					
	Nominal	.669	.183	-.016	-.032	.6280	.0041		1.99	.0048
		(7.71)	(3.16)	(4.05)	(2.11)					
1974:4	Real	.609	.208	-.015	-.045	.5870	.0049	-1.05		.0078
		(6.43)	(3.04)	(3.46)	(2.56)					
	Nominal	.728	.194	-.017	-.027	.7020	.0041		2.12	.0081
		(9.21)	(3.45)	(4.69)	(1.81)					
1975:4	Real	.567	.252	-.014	-.044	.5830	.0050	-.53		.0028
		(6.40)	(3.93)	(3.14)	(2.44)					
	Nominal	.709	.232	-.015	-.025	.6830	.0044		2.02	.0043
		(8.87)	(4.20)	(3.88)	(1.59)					
1976:4	Real	.564	.253	-.014	-.044	.5710	.0050	-.97		.0046
		(6.57)	(4.14)	(3.21)	(2.50)					
	Nominal	.700	.230	-.015	-.026	.6720	.0044		2.10	.0025
		(8.85)	(4.28)	(3.88)	(1.67)					

TABLE XL (Continued)

Endpoint	Adjustment	Δm_{t-1}	Δy_t	ΔRCP_t	ΔRTD_t	$\bar{R}^2$	S.E.E.	Durbin h	D.W.	Static 4Q RMSE
1977:4	Real	.555	.253	-.013	-.045	.5710	.0049	-1.01		.0071
		(6.54)	(4.20)	(3.11)	(2.56)					
	Nominal	.706	.226	-.014	-.026	.6720	.0043		2.12	.0045
		(9.10)	(4.33)	(3.90)	(1.68)					
1978:4	Real	.562	.237	-.014	-.042	.5420	.0050	-1.28		--
		(6.63)	(3.96)	(3.31)	(2.40)					
	Nominal	.717	.221	-.016	-.024	.6650	.0043		2.10	--
		(9.61)	(4.36)	(4.24)	(1.55)					

Source: Hafer and Hein (1980), p. 33. The sample period for all equations begin with 1955:3, and all equations are estimated using ordinary least squares. A constant term is included but is never significant.

Durbin-h statistics indicate a lack of autocorrelation in the residuals.[3] Finally, four-quarter static simulations[4] produce relatively small RMSEs.

Hafer and Hein (1980) conclude that the breakdown in the money demand equation is the result of estimating the equation in log-level form. When the equation is estimated in log-difference form, it is clear to Hafer and Hein that "the money demand relationship has not suffered from any drastic shifts that would invalidate monetary policy" (p. 35).

An Analysis of the Hafer and Hein Model

Hafer and Hein's (1980) model (equation 4-2) may be considered to be a special case of the more general transfer function model (Box and Jenkins, 1976). By this view, it is shown below that Hafer and Hein (1980) impose several a priori restrictions on their model. These restrictions are: (1) the explanatory and dependent variables are stationary[5] once they are first-differenced, (2) the explanatory variables affect the dependent variable with a distributed lag that follows an exponential decay, and (3) the error series follows a white

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[3]These tests are tests for AR(1) processes. By estimating (4-2) as a transfer function, one is able to test for higher order autoregressive processes as well as for moving average processes. This possibility is considered below.

[4]Hein (1980) shows that if one is interested in the temporal stability of a model, dynamic forecasting will exaggerate the errors associated with, say, a one-time shift. Dynamic forecasting will give the appearance of a continuous drift in the function.

[5]A series, X_t is stationary if $E(X_t) = E(X_{t+m})$, $E(X_t - \mu_X)^2 = E(X_{t+m} - \mu_X)^2$, and $Cov(X_t, X_{t+k}) = Cov(X_{t+m}, X_{t+m+k})$ for any t, m, and k (Pindyck and Rubinfeld, 1981).

noise process.[6] Transfer function modeling allows these restrictions to be determined empirically rather than being imposed a priori.

The money demand equation (equation 4-1) is estimated as a transfer function model and is used to forecast money demand in the post-1973 period. These results are compared to the estimation and forecasting results from equation (4-2). This evidence is presented following a description of transfer function modeling.

For the two variable case, the transfer function model is:

$$\begin{aligned} Y_t &= \upsilon_0 X_t + \upsilon_1 X_{t-1} + \dots + N_t \\ &= \upsilon(B) X_t + N_t \end{aligned} \tag{4-3}$$

where $\upsilon(B)$ = a polynomial operator representing the transfer function,

B = a backshift operator such that $BX_t = X_{t-1}$, $B^2 X_{t-1} = X_{t-2}$, etc, and

N_t = the sum of the effects of all variables other than X_t.

Equation (4-3) is a distributed lag model, and transfer function analysis involves obtaining the best model of $\upsilon(B)$.

By noting that a polynomial may be approximated as a ratio of two lower-ordered polynomials, equation (4-3) may be rewritten:

$$\upsilon(B) = \frac{\omega(B)}{\delta(B)} B^b \tag{4-4}$$

where $\omega(B)$ = a polynomial operator of order s,

$\delta(B)$ = a polynomial operator of order r, and

B^b = an operator representing the number of periods before X affects Y.

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[6]In equation (4-2), n_t is considered to be a white noise process if $E(n_t) = 0$ and $E(n_t^2) = \sigma_n^2$. n_t is sometimes assumed to be normally distributed (Box and Jenkins, 1976).

The $\omega(B)$ operator describes the more immediate effects of X on Y, while the $\delta(B)$ operator describes the pattern of their decay. Equation (4-3) may then be rewritten (supressing N_t):

$$Y_t = \frac{\omega(B)}{\delta(B)} B^b X_t \tag{4-5}$$

$$= \frac{(\omega_0 - \omega_1 B - \ldots - \omega_s B^s)}{(1 - \delta_1 B - \ldots - \delta_r B^r)} B^b X_t$$

or

$$Y_t(1 - \delta_1 B - \ldots - \delta_r B^r) = (\omega_0 - \omega_1 B - \ldots - \omega_s B^s) B^b X_t.$$

If X and Y are nonstationary, Box and Jenkins (1976) suggest differencing the data until X and Y are stationary. If only one difference is required, then (4-5) may be written:

$$y_t = \upsilon(B) B^b x_t + n_t \tag{4-6}$$

$$= \frac{(\omega_0 - \omega_1 B - \ldots - \omega_s B^s)}{(1 - \delta_0 B - \ldots - \delta_r B^r)} B^b x_t + n_t$$

where $y_t = Y_t - Y_{t-1}$,
$x_t = X_t - X_{t-1}$, and
$n_t = N_t - N_{t-1}$.

Values for r, s, and b are determined empirically through an identification process.[7] Once these values are determined, initial estimates of the $\upsilon(B)$ may be obtained.[8] One can then calculate the

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[7]See Box and Jenkins (1976), Pack (1977), or Helmer and Johansson (1977).

[8]For details, one may consult the references in footnote 7.

residuals by:

$$\hat{n}_t = y_t - \hat{\upsilon}(B)B^b x_t \ . \tag{4-7}$$

Using the time series methods of Box and Jenkins (1976), one may model the estimated noise series of n_t as a univariate model:

$$\phi(B)n_t = \theta(B)a_t \tag{4-8}$$

or

$$n_t = \phi(B)^{-1}\ \theta(B)a_t$$

where $\phi(B)n_t = n_t - \phi_1 n_{t-1} - \phi_2 n_{t-2}, \ldots,$ and

$\theta(B)a_t = a_t - \theta_1 a_{t-1} - \theta_2 a_{t-2}, \ldots$.

Therefore, the general form of the complete transfer function model is:

$$y_t = \frac{\omega(B)}{\delta(B)} B^b x_t + \phi(B)^{-1}\theta(B)a_t \tag{4-9}$$

Assuming r = 1, s = b = 0, and $n_t = a_t$, one has a transfer function model that is similar in appearance to the first-differencing model of Hafer and Hein. This model is:

$$y_t = \frac{\omega_0 x_t}{(1 - \delta_1 B)} + n_t \tag{4-10}$$

or

$$(1 - \delta_1 B)y_t = \omega_0 x_t + e_t, \qquad e_t = (1 - \delta_1 B)n_t$$

and

$$y_t = \delta_1 y_{t-1} + \omega_0 x_t + e_t$$

While the models are similar in appearance, the interpretation of the coefficient on the lagged dependent variable is different. The Hafer and Hein (1980) model utilizes the partial adjustment mechanism, and $1 - \delta$ represents the proportion of the gap between desired and actual money balances that is closed in the current period. In the transfer function model the coefficient on the lagged dependent variable measures the rate of decay of the distributed lags.

For the money demand equivalent of (4-5), differencing all variables one time achieves stationarity. In addition, the values of r, s, and b are determined to be 1, 0, and 0, respectively. A finding of r = 1 and s = 0 implies the explanatory variables affect m_t with an exponential decay. A finding of b = 0 implies that the explanatory variables affect m_t in the current period and not with a delay. Both of these implications are consistent with the restrictions imposed by Hafer and Hein on their model. The error series, however, is found to follow an IMA(1,1) process rather than a white noise process. The maximum likelihood estimates of (4-9) are:

$$\begin{aligned} \Delta m_t = {} & \underset{(2.78)}{(.1468)}/(1 - \underset{(3.31)}{.6400}\,B)\Delta y_t + \underset{(4.38)}{(-.0162)}/(1 - \underset{(9.56)}{.8000}\,B)\Delta RCP_t + \\ & \underset{(3.13)}{(-.0492)}/(1 - \underset{(5.35)}{.7000}\,B)\Delta RTD_t + (1 + \underset{(4.60)}{.3649}\,B)a_t \end{aligned} \qquad (4\text{-}11)$$

S.E.E. = .0046 Sample period = 1952:2-1973:4

Rearranging (4-11) gives:

$$\begin{aligned} (1 - .64B)(1 - .80B)(1 - .70B)\Delta m_t = {} & (1 - .80B)(1 - .70B)(.1468)\Delta y_t \\ & + (1 - .64B)(1 - .70B)(-.0162)\Delta RCP_t + (1 - .64B)(1 - .80B) \\ & (-.0492)\Delta RTD_t + (1 - .64B)(1 - .80B)(1 - .70B) \\ & (1 + .3649B)a_t \end{aligned} \qquad (4\text{-}12)$$

which is approximately:

$$(1 - .70B)^2(1 - .70B)\Delta m_t = (1 - .70B)^2(.1468)\Delta y_t + (1 - .70B)^2(-.0162)\Delta RCP_t + (1 - .70B)^2(-.0492)\Delta RTD_t + (1 - .70B)^2(1 - .70B)(1 + .3694B)a_t \quad (4\text{-}13)$$

or

$$\Delta m_t = .7000\ \Delta m_{t-1} + .1468\ \Delta y_t - .0162\ \Delta RCP_t - .0492\ \Delta RTD_t + (1 - .3351\ B - .2554\ B^2)a_t \quad (4\text{-}14)$$

Except for the error term, the form of (4-14) is indistinguishable from equation (4-2).

Equation (4-2) is re-estimated using the same data that is used to estimate the transfer function model. These results are:

$$\Delta m_t = .7153\ \Delta m_{t-1} + .1503\ \Delta y_t - .0162\ \Delta RCP_t - .0372\ \Delta RTD_t \quad (4\text{-}15)$$

$R^2 = .6431$ S.E.E. $= .0041$ D.W. $= 2.03$

Sample period = 1952:3-1973:4

Comparing (4-14) with (4-15), it is seen that the transfer function model and the log-difference model produce similar estimation results. This is not surprising since the only differences in the equations are in the estimation techniques and in the assumptions regarding the structure of the error series. The S.E.E. for the transfer function model, however, is somewhat larger.

Equations (4-14) and (4-15) are used to forecast money demand in the post-1973 period. The prediction errors from each equation are found in Table XLI. Regarding the static simulations, both models produce similar results, although the transfer function model (4-14)

TABLE XLI

PREDICTION ERRORS FROM EQUATIONS (4-14) AND (4-15)

Date and Summary Statistics		Equation (4-14)		Equation (4-15)	
Year	Quarter	Static Error	Dynamic Error	Static Error	Dynamic Error
1974	1	1.06	1.06	.092	0.92
	2	-3.18	-1.48	-1.70	-0.10
	3	-1.86	-4.95	-0.92	-1.77
	4	-1.50	-8.95	-1.73	-4.76
1975	1	-3.52	-15.27	-3.32	-10.30
	2	1.27	-18.42	.68	-13.90
	3	-0.99	-21.62	.14	-16.50
	4	-3.07	-26.93	-3.61	-22.10
1976	1	-0.70	-31.35	-0.72	-27.20
	2	-0.25	-34.52	1.29	-29.80
	3	-2.24	-38.98	-1.90	-33.80
	4	-0.42	-42.42	1.10	-35.80
1977	1	-1.61	-46.61	-2.79	-38.60
	2	-1.80	-51.27	-0.61	-41.10
	3	1.74	-52.79	1.57	-42.00
	4	-0.95	-54.80	1.80	-43.00
1978	1	-0.33	-56.54	-3.73	-44.10
	2	-2.41	-60.17	0.88	-44.90
	3	-0.47	-63.18	-1.04	-46.30
	4	-4.51	-69.80	-2.67	-50.70
RMSE		2.04	40.93	1.95	32.10
Mean Error		-1.29	-33.38	-0.82	-27.29
Mean Absolute Error		1.69	33.49	1.66	27.39

Note: These prediction errors are based on predictions from equations (4-14) and (4-15). The equations are expressed in level form, and the forecast of M_t is obtained by taking the antilogarithm of the predicted value of $\ln M_t$.

tends to overpredict relative to the log-difference model (4-15). Nevertheless, it is interesting to note that the errors from both equations are relatively small and do not tend to grow over time. The dynamic errors from both equations become negative in 1974 and grow increasingly larger (in absolute value) over time. This pattern is similar to that established by the Goldfeld (1976) equation in the post-1973 period.

Apparently, there is little to be gained in terms of coefficient estimates and forecasting results by estimating the transfer function model instead of the log-difference equation. Consequently, the remainder of the analysis of Hafer and Hein's (1980) proposal is conducted in terms of the log-difference model.

The log-difference model is re-estimated to include post-1973 observations. The results are similar for both adjustment versions, and only the results for the nominal adjustment version are presented. These results appear in Table XLII. For convenience, the results found in equation (4-15) are also included. The coefficient estimates differ in several respects from those in Table XL. The RTD variable does not become insignificant after 1973; the income elasticity is somewhat smaller; the coefficient on the lagged dependent variable shows a marked increase in 1974, but remains below .80. The S.E.E.s, on the other hand, are virtually the same. The model does not pass an F-test for structural stability when the break point is assumed to occur between 1974:4 and 1975:1 ($F(4,96) = 4.51$).

In an effort to learn more about a possible shift in the log-difference model, the stability tests of Brown, Durbin, and Evans (1975) are applied. These tests are (1) a time-trend, (2) the CUSUMS

TABLE XLII

ESTIMATES OF THE HAFER AND HEIN MONEY DEMAND MODEL FOR SELECTED YEARS

Endpoint	Δm_{t-1}	Δy_t	ΔRCP_t	ΔRTD_t	$\bar{R}^2$	S.E.E.	D.W.
1973:4	.7153 (9.67)	.1503 (3.44)	-.0162 (4.53)	-.0372 (2.59)	.6431	.0041	2.03
1974:4	.7703 (11.63)	.1550 (3.56)	-.0175 (5.12)	-.0331 (2.33)	.6927	.0041	2.13
1975:4	.7794 (11.53)	.1673 (3.83)	-.0156 (4.40)	-.0339 (2.27)	.6654	.0043	2.06
1976:4	.7714 (11.49)	.1634 (3.92)	-.0153 (4.36)	-.0342 (2.29)	.6578	.0043	2.16
1977:4	.7734 (11.73)	.1600 (4.00)	-.0151 (4.41)	-.0339 (2.31)	.6626	.0043	2.18
1978:4	.7827 (12.19)	.1567 (3.99)	-.0161 (4.78)	-.0325 (2.23)	.6562	.0043	2.15

Note: A constant term is included in these equations but is never significant. Each sample period begins with 1952:3 and the endpoint is moved forward four quarters each time the equation is estimated. All equations are estimated using ordinary least squares.

test, (3) the CUSUMS-squared test, and (4) the Quandt (1960) log-likelihood ratio test.

In the time-trend test, a time factor is entered into the equation. Specifically, the regression coefficients are allowed to become polynomials in time. In order to determine whether the extended model produces a better fit than the original model and in order to determine what degree of polynomial is appropriate, the sum of squares removed by each of the following equations is calculated:[9]

$$
\begin{aligned}
y_t &= \beta_1 x_t + e_t \\
y_t &= (\beta_1 + \beta_2 t)x_t + e_t \\
y_t &= (\beta_1 + \beta_2 t + \beta_3 t^2)x_t + e_t \\
&\vdots \\
y_t &= (\beta_1 + \beta_2 t + \beta_3 t^2 + \dots + \beta_{e+1} t^e)x_t + e_t
\end{aligned}
$$

The time trend test compares the mean-square increase in the explained variation with an estimate of the error variance. This provides an F-test for determining whether a given model gives a significantly better fit than the one before.

In the CUSUMS test, the model is estimated for r sample periods where r = k + 1, ..., T and k and T are, respectively, the number of regressors and the total number of observations. As a particular equation is estimated, the sum of the one-step-ahead errors is recorded. The cumulative sum of the prediction errors from the T-k equations is used to construct a statistic, which if greater than

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[9]For simplicity, a two variable model is considered.

a critical value, indicates the regression relationship is not stable over time. The CUSUMS-squared test, though similar to the CUSUMS test, uses the square of the prediction errors in generating the test statistic. The critical values for both the CUSUMS and the CUSUMS-squared tests are given in Evans (1973).

Should either test indicate a lack of stability, it is possible to identify the exact point in time when the suspected shift takes place. This is done by noting whether or not the cumulative sum of the errors (or the sum of the squared errors) at time k+j (j = 1, 2, ..., T-k) falls outside a confidence band for a given level of significance. If the cumulative sum falls outside the band, then this is indicative of a shift at period k+j.

Quandt's (1960) log-likelihood ratio test is useful under the assumption of a one-time shift at an unknown point. For each observation from k+1 to T-k-1, the statistic

$$\ln \lambda_r = \tfrac{1}{2} r \ln (\sigma_1^2) + \tfrac{1}{2}(T-r) \ln (\sigma_2^2) - \tfrac{1}{2} T \ln (\sigma_T^2)$$

is calculated where

σ_1^2 = the estimated error variance for the equation estimated over the first r observations (r = k+1, k+2, ..., T-k-1),

σ_2^2 = the estimated error variance for the equation estimated for the last T-r observations, and

σ_T^2 = the estimated error variance for the equation estimated for all T observations.

A test for $\ln \lambda_r$ is not available, but the way $\ln \lambda_r$ varies at different observations gives some information on the behavior of the regression relationship over time. In particular, $\ln \lambda_r$ is expected to reach a minimum at the point of change in the regression relationship. This result is expected since σ_T^2 is obtained from data belonging to two different economic structures, while σ_1^2 and σ_2^2 are obtained from data belonging to single economic structures. As the point of change is approached, the sum $\sigma_1^2 + \sigma_2^2$, should decline. Since σ_T^2 is fixed, $\ln \lambda_r$ should decline as well. At the point of change the quantities, $\sigma_1^2 + \sigma_2^2$ and $\ln \lambda_r$, should reach their respective minimums. If there is no structural change in the regression relationship, then $\ln \lambda_r$ should not take on an obvious V-shape, and values of $\ln \lambda_r$ should be close to zero.

The results of the various tests are presented in Table XLIII. The results are not at all definitive. The time-trend, CUSUMS, and CUSUMS-squared tests imply the log-difference model is stable over the entire 1952-1978 period. On the other hand, the log-likelihood ratio test implies that the money demand function is not stable. The ratio takes on a V-shape and reaches a minimum at 1977:1. This implies that a shift occurs at that point. This result conflicts with the F-test which suggests a shift takes place between 1974:4 and 1975:1.

It is puzzling that the stability tests are not consistent. Kahn (n.d.) obtains similar results for the money demand function that is estimated by Heller and Kahn (1979) and can only conclude that the CUSUMS, CUSUMS-squared, and the time trend tests are less powerful when a shift occurs toward the end of the sample period.[10] In a Monte Carlo study, Garbade (1977) finds the power of the CUSUMS and the CUSUMS-squared tests to decline in the case of a discrete shift in the function.

---

[10]The Heller and Kahn (1979) model is shown to be stable by the Brown, Durbin, and Evans (1975) tests for the 1960-1976 period. When Kahn (n.d.) estimates the model through 1974, the model significantly overpredicts nominal money balances in a post-1974 dynamic simulation.

TABLE XLIII

STABILITY TESTS FOR THE HAFER AND HEIN MONEY DEMAND EQUATION (NOMINAL ADJUSTMENT)

Time-Trend Regressions		CUSUMS[a]	CUSUMS-Squared[b]	Log-Likelihood Test	
				Minimum Value	Date
e=1	$F(4,94) = .3214$	.3652	.1470	-6.39	1977:1
e=2	$F(4,94) = .4808$				

[a]Critical values at the .01 and .05 levels are, respectively, 1.143 and .948 and are taken from Evans (1973).

[b]Critical values at the .01 and .05 levels are, respectively, .2115 and .1747 and are taken from Evans (1973).

It is also puzzling that the coefficient estimates of the log-difference equation (Table XLII), as well as the results from the static simulations of the log-difference and transfer function models (Table XLI) do not strongly point to a structural shift in the money demand function. In the log-level model, the coefficient estimates and the simulation errors clearly point to a change in the money demand relationship.

One explanation for the Hafer and Hein's (1980) results is that difference equations are less sensitive to a one-time shift in the slope coefficients than are levels equations. In other words, a one-time shift could occur in the slope coefficients and not be apparent in the coefficient estimates and in the simulation results from the log-difference equation. Also, F-tests for structural stability may not necessarily expose the shift. The argument that difference equations are less sensitive to one-time shifts in the slope coefficients is developed within the Goldfeld (1976) equation, although the results can be generalized to any difference equation experiencing this shift.

From the Porter-Mauskopf (n.d.) explanation of Chapter III, one may conclude that, beginning in the mid-1970s, the correct model is not (4-2) but is:[11]

$$\Delta m_t = \beta_1 \Delta m_{t-1} + (\beta_2 - A_2) \Delta y_t + \beta_3 \Delta RCP_t + \beta_4 \Delta RTD_t + n_t \quad (4\text{-}16)$$

The A_2 term is included to reflect the one-time reduction in the income elasticity of money demand that is implied by the Porter-Mauskopf (n.d.) model.

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[11] The log notation is omitted for simplicity.

Even though (4-2) experiences a structural shift so that (4-16) becomes the correct model in the mid-1970s, the OLS estimates of (4-2) give the appearance of stability (Table XLI). An explanation for this is developed by noting the OLS estimator is expressed as $S_{xx}^{-1} S_{xy}$. The first term in the expression is the matrix of cross-products of the explanatory variables, and the second term is the matrix of cross-products of the explanatory and dependent variables. A one-time change in the relationship between the explanatory and dependent variables in level form[12] is expected to bring about larger changes in the S_{xy} and S_{xx} matrices and therefore in greater changes in the coefficient estimates than in the log-difference model. The reason for this is there is less correlation in the differenced series to begin with. A change in the relationship between the levels variables at time t+j may produce only a minor change in the correlation between the first difference of these series. This causes only minor changes in the coefficient estimates of the log-difference model as the sample is extended beyond time t+j. Consequently, casual inspection of the coefficient estimates of the log-difference model does not give the impression of model instability. Hafer and Hein's (1980) estimation results are therefore inconclusive.

The change in the money-income relationship is not necessarily suggested by the static simulation errors from (4-2). The expected value of the static error from (4-2) is:[13]

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[12]More specifically, the Cochrane-Orcutt technique produces the quasi-difference model, $y_t - \rho y_{t-1} = (1 - \rho)\beta_0 + \beta_1(x_t - \rho x_{t-1}) + N_t$.

[13]The expectation is derived by expressing (4-2) and (4-16) in

$$E(m_{t+1} - \hat{m}_t(1)) = -A_2\ \Delta y_{t+1} \tag{4-17}$$

The expectation in (4-17) is biased and is negative (money balances are overpredicted) for the 1975:2-1978:4 period since $\Delta y_{t+1} > 0$ for this period. This negative expectation, however, is absolutely smaller than the expected value of the static error from the log-level model (equation 4-1). This is seen by noting the expected value of the static error from (4-1) is:[14]

$$E(m_{t+1} - \hat{m}_t(1)) = -A_2\ y_t > 0 \tag{4-18}$$

Subtracting (4-18) from (4-17) gives:

$$\begin{aligned} -A_2\ \Delta y_{t+1} + A_2\ y_{t+1} &= -A_2\ y_{t+1} + A_2\ y_t + A_2\ y_{t+1} \\ &= A_2\ y_t > 0 \end{aligned} \tag{4-19}$$

Since both expectations are negative to begin with (between 1975:2 and 1978:4), the positive value in (4-19) shows the expectation in (4-17) is absolutely smaller than the expectation in (4-18). Consequently, while the static errors from the log-level model take on a definite

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level form:

$$\begin{aligned} m_t = m_{t-1} + \beta_1\ \Delta m_{t-1} + (\beta_2 - A_2)\ \Delta y_t + \beta_3\ \Delta RCP_t + \\ \beta_4 \Delta RTD_t + n_t \end{aligned} \tag{4-16}$$

$$m_t = m_{t-1} + \beta_1\ \Delta m_{t-1} + \beta_2\ \Delta y_t + \beta_3\ \Delta RCP_t + \beta_4\ \Delta RTD_t + n_t \tag{4-2}$$

Therefore

$$\begin{aligned} E(m_{t+1} - \hat{m}_t(1)) &= -A_2\ \Delta y_{t+1} + E(n_{t+1}) \\ &= -A_2\ \Delta y_{t+1} \end{aligned}$$

[14]This expectation is derived in a manner similar to that for equation (4-17). See footnote 13.

negative pattern, the static errors from the log-difference model are on average negative but are smaller in magnitude. This indicates that Hafer and Hein's (1980) simulation results are ambiguous since they, like the estimation results, would have been obtained for a stable model or for an unstable model.

The dynamic simulation errors from the log-difference model, unlike the static errors, give the appearance of a structural shift in equation (4-2) (Table XLII). The pattern of the dynamic errors, however, is entirely consistent with that from the static simulation. This is true because the dynamic error from (4-2) for time t+j is a function of the static errors for periods t+j-i (i = 0, 1, ..., j-1).[15] Since equation (4-2) is in log-difference form, a formal expression of this functional relationship is rather complicated. To simplify matters, it is shown here that the dynamic error for time t+j is a function of the static error for t+j and the dynamic errors for time t+j-k (k = 1, 2). This relationship is given as:[16]

$$\hat{n}_t(j) = \hat{n}_{t+j-1}(1) - A_2\,\Delta y_{t+j} + (1 + \beta_1)\,\hat{n}_t(j-1) - \beta_1\hat{n}_t(j-2) \qquad (4\text{-}20)$$

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[15]See Hein (1980).

[16]This relationship is derived as:

$$\begin{aligned} m_{t+j} - \hat{m}_t(j) &= m_{t+j-1} + \beta_1(m_{t+j-1} - m_{t+j-2}) + (\beta_2 - A_2)\,\Delta y_{t+j} + \\ &\quad \beta_3\,\Delta RCP_{t+j} + \beta_4\,\Delta RTD_{t+j} + n_{t+j} - \hat{m}_t(j-1) - \\ &\quad \beta_1(\hat{m}_t(j-1) - \hat{m}_t(j-2)) - \beta_2\,\Delta y_{t+j} - \beta_3\,\Delta RCP_{t+j} - \\ &\quad \beta_4\,\Delta RTD_{t+j} \\ &= \hat{n}_{t+j-1}(1) - A_2\,\Delta y_{t+j} + (1 + \beta_1)\hat{n}_t(j-1) - \beta_1\hat{n}_t(j-2). \end{aligned}$$

where $\hat{n}_t(j)$ = the dynamic error for time t+j,

$\hat{n}_{t+j-1}(1) - A_2\, \Delta y_{t+j}$ = the static error for time t+j,

$\hat{n}_t(j-1)$ = the dynamic error for time t+j-1, and

$\hat{n}_t(j-2)$ = the dynamic error for time t+j-2.

That the dynamic errors become negative in 1974 and grow in absolute value over time (Table XLI) is the result of the model's tendency to overpredict in the early stages of the static simulation. For example, the relatively large static errors at 1975:1 and 1975:4 are enough to insure large and growing dynamic errors unless the static errors soon become positive and large.[17]

Stability tests are also inconclusive and may accept the hypothesis of stability if the tests are based upon the one-step-ahead (static) forecast errors. Since these errors are understated (in absolute value) to begin with, the tests are biased toward accepting the hypothesis of stability. This may explain why the stability tests of this chapter are not definitive. The F-test and the log-likelihood ratio test reject the hypothesis of stability, but there is a lack of agreement as to where the shift occurs. The other tests (Table XLIII) accept the hypothesis of stability.

While the above analysis rejects Hafer and Hein's (1980) results as being ambiguous, one may also show the log-difference model is not superior to the log-level model in terms of predictuve performance even during a period of relative stability for both equations.

In this analysis, each equation is estimated for sample periods covering 1952-1961, 1952-1962, ..., 1952-1972. These equations are

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[17]The fact that the coefficient on $\hat{n}_t(j-1)$ is positive and greater than unity also contributes to the pattern of the dynamic errors.

used in four-quarter dynamic simulations and in dynamic simulations that extend through 1973:4. The RMSEs from these simulations are found in Table XLIV. While both models track nominal money demand relatively well, the log-level model generally obtains the lower RMSE. For the extended simulations, the log-level model obtains the lower RMSE in six of the 11 simulations and is even better in the four-quarter simulations, achieving the lower RMSE in nine of the 12 simulations. While these results do not suggest it is wrong to use the log-difference form, they serve to point out that it is not necessarily inappropriate, from a forecasting standpoint, to use the log-level form.

Summary

Hafer and Hein (1980) argue the demand for money function remains stable in the mid-1970s, and the so-called money demand problem is more apparent than real. They believe the problem is one of using an incorrect estimation technique and present evidence suggesting the instability is no longer evident when all variables are differenced prior to estimation using ordinary least squares.

This chapter analyzes the Hafer and Hein explanation. It is shown that Hafer and Hein's log-difference equation may be considered to be a special case of the transfer function model. A transfer function model is estimated and is used to forecast money demand in the post-1973 period. These results are compared to those from the Hafer and Hein log-difference equation. Both sets of results are found to be similar. It is concluded that there is little to be gained in terms of the coefficient estimates and forecasting performance by estimating the money demand function as a transfer function model.

TABLE XLIV

DYNAMIC SIMULATION RESULTS FROM LOG-LEVEL AND LOG-DIFFERENCE MONEY DEMAND MODELS

Estimation Period	Model	Four Quarter RMSE	End-of-Sample RMSE
1952-1961	Log-Level	0.75	2.81
	Log-Difference	0.55	2.51
1952-1962	Log-Level	1.15	3.32
	Log-Difference	1.25	2.33
1952-1963	Log-Level	0.58	4.97
	Log-Difference	0.62	5.25
1952-1964	Log-Level	1.07	7.70
	Log-Difference	1.71	6.68
1952-1965	Log-Level	2.40	6.53
	Log-Difference	2.96	7.10
1952-1966	Log-Level	1.15	3.12
	Log-Difference	3.70	7.99
1952-1967	Log-Level	1.64	2.81
	Log-Difference	1.15	3.52
1952-1968	Log-Level	1.81	6.48
	Log-Difference	2.71	8.77
1952-1969	Log-Level	0.88	4.18
	Log-Difference	1.46	2.90
1952-1970	Log-Level	2.26	5.51
	Log-Difference	2.40	4.55
1952-1971	Log-Level	2.14	3.80
	Log-Difference	3.80	6.65
1952-1972	Log-Level	0.68	--
	Log-Difference	0.65	--

Hafer and Hein's equation is re-estimated to include more recent observations. The coefficient estimates and the static errors do not show the same deterioration as the log-level equation. An F-test and the log-likelihood ratio test reject the hypothesis of stability, but the tests are not in agreement regarding the timing of the shift. Additional stability tests, however, accept the hypothesis of stability. An explanation for these inconsistencies is developed. It is shown that Hafer and Hein's results are inconclusive and would be obtained for a stable model or an unstable model.

CHAPTER V

SUMMARY OF EMPIRICAL RESULTS

Introduction

This study examines the transactions demand for money model with particular emphasis on the 1974-1978 period when money demand models begin to overpredict. Several models explaining the money demand problem appear in the literature. Each of the models has some appeal and in certain cases, empirical support. Nevertheless, these models are largely inconsistent with one another which suggests they are not all correct.

The purpose of this study, therefore, is to examine these models in an effort to eliminate some as acceptable explanations to the money demand problem, and hence to narrow the ground for debate concerning the overpredictions of money demand.

The models explaining the demand for money in the post-1973 period are grouped into three broad categories--the definitional explanation, the omitted variable explanation, and the incorrect estimation technique explanation. These models are analyzed using a common data set, more recently revised data, and a common sample period.

The evidence from this study points to the conclusion that a one-time shift occurs in the money demand equation in the mid-1970s. At the same time, the evidence rejects the definitional and the incorrect estimation technique arguments, while indirectly supporting the omitted variable explanation. Specifically, the results show that a relatively large portion of the demand shift is due to a one-time reduction in the income elasticity of money demand. This result is consistent with the Porter-Mauskopf (n.d.) model. A summary of the empirical results is given below.

The Definitional Explanation

The definitional explanation states the money demand problem occurs because the M-1 definition of transactions balances is incorrect beginning the mid-1970s. This definitional problem is presumed to have occurred because several new financial instruments, developed in the 1970s, are used by money holders as transactions balances. Since the M-1 definition excludes these new financial assets, it is reasonable to expect money demand equations using M-1 as the dependent variable will overpredict money demand. By this explanation, the solution to the problem is in estimating money demand models that expand the definition of money to include the new financial assets. When this is done, the researchers supporting the definitional explanation find the overpredictions of money demand are eliminated.

In analyzing the definitional explanation, this study first demonstrates the empirical results that are obtained by those espousing this explanation are in fact ambiguous. This result is used to argue that the ambiguity occurs because the explanation is tested from the money demand side rather than from the money supply side. This study shows that if the definitional explanation is correct, then money supply models should also significantly overpredict in the mid-1970s. Such overpredictions would unambiguously support the definitional explanation.

ARIMA models and single equation regression models of the money supply process are estimated for the 1952-1973 period and are then used in post-1973 simulations. In all cases the models obtain statistically significant coefficients, and in the regression models the coefficients obtain the theoretically anticipated signs. When used in post-sample simulations, these models track their respective series quite accurately. The single equation regression models also pass tests for structural stability for the 1952-1973 and 1974-1978 periods.

The implication of these results is that whatever the source of the money demand problem in the mid-1970s, the problem is not due to the increasing development and use of certain checkable deposits and nondeposit assets. This study, therefore, rejects the definitional explanation.

The Omitted Variable Explanation

The omitted variable explanation attributes the money demand problem to the omission of a particular variable from the money demand function. Those most notable in this regard are Hamburger (1976), Friedman (1979), Quick and Paulus (n.d.), Porter and Mauskopf (n.d.), and Kimball (1980). According to this explanation, the solution to the problem is to identify and to include the omitted variable in the money demand function.

In developing their arguments, Hamburger and Friedman appeal to a more general model of money demand. Hamburger (1976) includes a long-term bond rate and a yield on real capital--the dividend-price ratio--among the explanatory variables. He also constrains the long-run income elasticity to be unity. Friedman (1979) utilizes Hamburger's framework but replaces the dividend-price ratio with a real wealth variable.

The analysis of Chapter III questions the validity of these two solutions to the money demand problem. This study finds the constraint placed on the long-run income elasticity is inappropriate. Once this constraint is relaxed, the respective models deteriorate in a manner similar to the Goldfeld (1976) equation either in terms of the coefficient estimates or in terms of the simulation results. Consequently, this study does not accept the particular models of Hamburger (1976) and Friedman (1979).

Quick and Paulus (n.d.), Porter and Mauskopf (n.d.), and Kimball (1980) all attribute the problem to the omission of a variable reflecting the utilization of cash management techniques by firms and household units. A more intensive use of these techniques reduces the demand for money at any given income and interest rate levels.

In order to capture the use of these cash management techniques, Quick and Paulus (n.d.) include a past-peak interest rate variable in their money demand equation; Porter and Mauskopf (n.d.) work within the Miller-Orr framework and replace real income with the variance of business firm cash flow; Kimball (1980) includes the number of wire transfers as his cash management variable. With the exception of Porter and Mauskopf (n.d.), the above researchers find empirical support for their models. Porter and Mauskopf are unable to test their model empirically since a measure of business firm cash flow variance is unavailable.

The analysis of Chapter III does not support the specific models proposed by Quick and Paulus (n.d.) or Kimball (1980). The Porter-

Mauskopf (n.d.) explanation, however, is indirectly supported. Their model implies a one-time shift in the money demand function, and that a significant share of this shift is due to a one-time reduction in the income elasticity of money demand. The pattern of the static simulation errors from the Goldfeld (1976) equation appears to confirm that a one-time shift takes place in the mid-1970s. The dummy variable model of Chapter III supports this implication and at the same time indicates that a major portion of the shift is due to a reduction in the income elasticity coefficient. Within this same dummy variable model, the coefficients on the m_{t-1}, RCP, and RTD variables display remarkable stability. Finally, the dummy variable model predicts money demand very well for the 1976-1978 years.

Chapter III also examines the impact of inflationary expectations on money demand in the mid-1970s. An inflation variable is considered for two reasons. The role of expected inflation in the money demand problem is given little attention in the literature. Also, consideration of this variable is useful because it permits a test of the hypothesis that the money demand function experiences a continuous, downward drift in the post-1973 period. Two models of inflation are estimated and are used to generate one-step-ahead forecasts of inflation. These forecasts are taken to be measures of expected inflation. Each expected inflation series is entered into three different money demand equations. The inflation variables attain significance in only one of the three money demand functions but do nothing to explain the demand for money between 1974 and 1978. This result is consistent with that given in Goldfeld (1976) and is also consistent with the one-time shift hypothesis.

The Incorrect Estimation Technique Explanation

The final explanation that is considered is that which denies the money demand function shifts in the first place. Hafer and Hein (1980) present evidence suggesting the money demand problem vanishes when the function is estimated in log-difference form using ordinary least squares. When the money demand relationship is estimated in log-difference form, the coefficient estimates as well as the static simulation, give every indication of stability in the post-1973 period.

The analysis of Chapter IV demonstrates the log-difference model may be considered to be a special case of the more general transfer function model. A transfer function model is estimated and simulated. The results are similar to those given by Hafer and Hein. Thus, the remainder of the analysis of the Hafer and Hein proposal is conducted in terms of the log-difference model.

Using the data of this study, Hafer and Hein's results are essentially replicated. Hafer and Hein find their model passes F-tests for stability. However, a series of stability tests in Chapter IV produce mixed results regarding the stability issue.

An explanation is developed to explain why the log-difference model produces acceptable coefficient estimates and simulation results, yet produces mixed results in a series of stability tests. It is shown that the log-difference model is not sensitive to a one-time shift in the slope coefficients. The conclusion is that the coefficient estimates, the simulation results, as well as the stability tests may not expose a change in the money demand relationship. Hafer and Hein's results are considered to be inconclusive.

Implications for Monetary Policy

The instability of the money demand relationship that surfaces in the mid-1970s leads some economists to question the use of money as an indicator of policy or as a policy instrument in favor of a policy centered around a measure of interest rates. The results that are obtained in this study question this conclusion since the money demand function is found to experience a one-time shift between 1974 and 1978 and is not subject to a continuous, downward drift over time.

It is possible to interpret these results as supporting the use of money as a policy instrument. The reason for this is that the breakdown in money demand occurs during a period in which the Fed follows an interest rate procedure in controlling the money supply. The attempt to smooth interest rates, however, may result in monetary growth rates that are inconsistent with the goal of price stability. In this case, inflationary pressures may accumulate and bring about relatively high interest rate levels. The attempt to smooth interest rates in the mid-1970s could therefore be responsible for the historically high interest rates of that period. To the extent that the utilization of money management techniques and money demand in particular are affected by these events, then the Fed's own policy of money supply control may in part be responsible for the shift that takes place in the mid-1970s.[1]

Implications for Additional Research

This study has implications for additional research in the area of money demand. Since interest rates once again reach record high levels

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[1] See Quick and Paulus (n.d.).

in 1980, another discrete shift in money demand is to be expected. Such a shift would occur as money holders engage in another round of cash management innovation. While it may be convenient for one to attribute all of any shift that may occur to the adoption of ATS and NOW accounts,[2] researchers should attempt to determine what portion of any shift is due to another round of cash management innovation and what portion is due to an incorrectly defined monetary aggregate. This analysis could begin with an extension of the money supply models of Chapter II and with an extension of the dummy variable model of Chapter III.

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[2]In December, 1979, Congress extended the authority for ATS accounts to March 31, 1980. Congress also extended NOW accounts to New Jersey at this time.

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VITA

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